# Declaration

I, Hiroko Mishima, a member of Hayase & Company Patent Attorneys of 8F, ANA Bldg., 17-1, Enoki-cho, Suita-shi, Osaka 564, Japan, hereby declare that I am the translator of the attached document and certify that the following is a true translation to the best of my knowledge and belief.

Osaka, this 30th day of June, 1999

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[Title of Invention] Focus servo system and optical recording/ reproducing apparatus

[Claims]

[Claim 1] A focus servo system comprising: focusing means for focusing a light beam on a recording medium having plural recording/reproducing faces which are laminated; moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium face; focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium; initial lead-in face detecting means for driving the moving means at the starting or resuming of the apparatus, and detecting recording/reproducing face of the recording medium which is reached first by the focal point of the light beam when the focusing means goes away from the recording medium after approaching the recording medium or when the focusing means approaches the recording medium after going away from the recording medium; and focus control means for driving the moving means in response to an output signal from the focusing state detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium, said focus control means being driven in response to a signal from the initial lead-in face detecting

means.

[Claim 2] A focus servo system comprising: focusing means for focusing a light beam on a recording medium having plural recording/reproducing faces which are laminated; moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium face; focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium; focus control means for driving the moving means in response to an output signal from the focusing state detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium; and focus jumping means for driving the moving means by switching the state of the focus control means from an operation state into a non-operation state and moving the focal point of the light beam from a recording/reproducing face to another recording/reproducing face on the recording medium, said focus jumping means comprising: accelerating/decelerating means for accelerating/decelerating moving speed of the focal point of the light beam on the basis of the signal from the focusing state detecting means; and jumping lead-in means for detecting a recording/reproducing face of a moving destination on the basis of a prescribed level reached by the signal from the focusing state detecting means, and re-operate the focus control means.

[Claim 3] The focus servo system as defined in claim 2 comprising: S signal measuring means for measuring an amplitude of a signal from the focusing state detecting means at every passing of the focal point of the light beam through the recording medium when the moving means is driven at the starting or resuming of the apparatus and the focusing means goes away from the recording medium after approaching the recording medium or approaches the recording medium after going away from the recording medium; gain change means for changing a gain of the focusing state detecting means in accordance with the amplitude measured by the S signal measuring means so that the gain is optimum for each recording/reproducing face; and the jumping lead-in means detecting that the focal point of the light beam reaches each recording/reproducing face on the recording medium by a prescribed level which is reached by a signal from the focusing state detecting means passing through the gain change means, in accordance with the amplitude measured by the S signal measuring means, and re-operating the focus control means.

[Claim 4] The focus servo system as defined in claim 2 wherein amplitudes of an acceleration signal and a deceleration signal which are generated by the accelerating/decelerating means or integrated values of the amplitudes has a relationship given by the amplitude of the acceleration signal or the integrated value thereof > the amplitude of the deceleration signal or the integrated value, when the focal point of the light

beam moves from a surface to an inner part of the recording medium, and the amplitude of the acceleration signal or the integrated value thereof < the amplitude of the deceleration signal or the integrated value when the focal point of the light beam moves from the inner part to the surface of the recording medium.

[Claim 5] A focus servo system comprising: focusing means for focusing a light beam on a recording medium having a track on which a concave signal and a convex signal in a pit part and a mirror part are recorded in advance; first signal detecting means for detecting a signal increasing when the light beam focused by the focusing means is shifted toward a positive direction with relative to the recording medium; second signal detecting means for detecting a signal increasing when the light beam focused by the focusing means is shifted toward a negative direction with relative to the recording medium; first and second peak hold means for peak holding parts corresponding to mirror parts of the first and second signal detecting means; first focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium by the first and second peak hold signals; moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium face; and focus control means for driving the moving means in response to an output signal from the first focusing state detecting means and controlling the light beam

so that the light beam is focused at an approximately fixed position on the recording medium.

[Claim 6] The focus servo system as define in claim 5 comprising: tracking control means for controlling the light beam so that the light beam scans the track correctly on the recording medium; and second focusing state detecting means for generating signal corresponding to a focusing state of the light beam on the recording medium by the first and second signal detecting means, wherein at starting of the apparatus or seeking of a prescribed track, the focus control means is driven in response to output from the first focusing state detecting means when the tracking control means is turned off, and the focus control means is driven in response to output from the second focusing state detecting means when the tracking control means is turned on.

[Claim 7] An optical recording/reproducing apparatus comprising: focusing means for focusing a light beam on a recording medium having plural recording/reproducing faces which are laminated: first moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium; second moving means for moving the focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium and the track; focusing state detecting means for generating a signal corresponding to a focusing state

of the light beam on the recording medium; track error detecting means for generating a signal corresponding to a positional relationship between the focal point of the light beam on the recording medium and the track; focus control means for driving the first moving means in response to an output signal from the focusing state detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium; tracking control means for driving the second moving means in response to an output signal from the track error detecting means and controlling the light beam so that the focal point of the light beam scans the track correctly on the recording medium; and focus jumping means for driving the moving means by switching the state of the focus control means from an operation state into a non-operation state and moving the focal point of the light beam from a recording/reproducing face to another recording/reproducing face on the recording medium; and further comprising: learning means for driving the focus control means and the tracking control means on each recording/reproducing face of the recording medium at starting of the apparatus, and learning and selecting a set value which is necessary in each control means; and storing means for storing the set value, wherein said learning means selects the set value corresponding to a recording/reproducing face of a moving destination which is stored in the storing means when the learning means is moved

on the recording/reproducing face by the focus jumping means after completion of the learning on each recording/reproducing face.

[Claim 8] The optical recording/reproducing apparatus as defined in claim 7 wherein the learning means comprises: eccentricity measuring means for measuring an eccentricity on each recording/reproducing face of the recording medium; and eccentricity correction value calculating means for calculating a correction value to be added to or subtracted from a signal from the tracking control means on the basis of a value measured by the eccentricity measuring means, the set value in the learning means being information calculated by the eccentricity correction value calculating means.

[Claim 9] The optical recording/reproducing apparatus as defined in claim 7 wherein the learning means comprises: focus offset measuring means for calculating an offset of the focus control means by an amplitude, a jitter, an error rate, or C/N of a reproducing signal on each recording/ reproducing face on the recording medium; and focus offset correction means for correcting the offset by performing addition or subtraction to the signal from the focus control means on the basis of the offset value of the focus offset measuring means, set value in the learning means being the correction value of the focus offset correcting means.

[Claim 10] The optical recording/reproducing apparatus as

defined in claim 7 wherein the learning means comprises: tracking offset measuring means for calculating an offset of the tracking control means by a reproducing signal or a signal from the track error detecting means on each recording/ reproducing face on the recording medium; and tracking offset correcting means for correcting the offset by performing addition or subtraction to the signal from the tracking control means on the basis of the offset value of the tracking offset measuring means, the set value in the learning means being a correction value of the tracking offset correcting means.

[Claim 11] The optical recording/reproducing apparatus as defined in claim 7 wherein the learning means comprises: gain measuring means for measuring a loop gain of the focus control means or the tracking control means; and gain change means for changing the loop gain of the focus control means or the tracking control means on the basis of a signal from the gain measuring means so as to have an optimum value, the set value in the learning means being a change value which is set by the gain change means.

[Detailed Description of the Invention]

[0001]

[Applicable Field in the Industry]

The present invention relates to an optical recording/ reproducing apparatus which optically records signals on a recording medium using a light beam emitted from a light source such as a laser and reproduces the recorded signals. More

specifically, the invention relates to a focus servo system for controlling a focusing state of the light beam irradiating the recording medium so that the light beam is focused on a prescribed position of the recording medium, and further relates to the optical recording/reproducing apparatus equipped with the focus servo system.

[0002]

[Prior Art]

As a prior art focus servo system, there is an optical recording/reproducing apparatus in which a light beam emitted from a light source such as a semiconductor laser is focused on a disk type recording medium rotating at a prescribed rotating speed, and signals are recorded on or reproduced from the recording medium. The recording medium has spiral or concentric micro-tracks having a width of 0.6 $\mu m$ and a pitch of 1.5 $\mu m$. In order to record signals on the tracks or reproduce signals recorded on the tracks, focusing of the light beam irradiating the recording medium is controlled so that the light beam is focused on a prescribed position of the recording medium in these optical recording/reproducing apparatus.

[0003]

Figure 16 is a block diagram illustrating a simple structure of a recording/reproducing apparatus including the prior art focus servo system. Hereinafter, the prior art focus servo system will be described with reference to figure 6.

[0004]

As shown in the figure, the prior art recording/reproducing apparatus comprises a light source 1 such as a semiconductor laser, which is an optical system for emitting a light beam 8 toward a disk 7 as a recording medium, a coupling lens 2, a polarization beams splitter 3, a polarizing plate 4, a focusing lens 5, and a disk motor 6 for rotating the disk 7 at a prescribed rotating speed. The light beam 8 emitted from the light source 1 is collimated by the coupling lens 2. Then, after the collimated beam is reflected by the polarization beam splitter 3, the light beam travels through the polarizing plate 4 and is focused by the focusing lens 5 on the disk 7 rotated by the disk motor 6.

[0005]

This recording/reproducing apparatus further comprises a condenser lens 9 and a split mirror 10 as elements for receiving a light beam reflected at the disk 7. The light beam reflected at the disk 7 travels through the focusing lens 5, polarizing plate 4, the polarization beam splitter 3, and the condenser lens 9, and is split into light beams 11 and 15 in two directions by the split mirror 10. The light beams 11 and 15 are applied to a focus servo system and a tracking servo system, respectively.

[0006]

The focus servo system comprises a two-element

photodetector 12, preamplifiers 13A and 13B, a differential amplifier 14, a phase compensation circuit 18, a linear motor 19, a switch 33, a driving circuit 35, a focus control element (focus actuator) 36, a logic circuit 40, a comparator 41, and a chopping wave generator 42. The photodetector 12 has two light responsive parts A and B. Output signals from the light responsive parts A and B are amplified by the preamplifiers 13A and 13B, respectively, and input to the differential amplifier 14. Here, a knife edge detection is realized by the condenser lens 9 and split mirror 10, and a signal output from the differential amplifier 14 is a focus error signal (FE signal).

[0007]

The phase of the FE signal in the focus servo system is compensated by the phase compensation circuit 18, and input to the driving circuit 35 through the switch 33 for closing a loop of the focus servo system. When the focus servo system is closed by the switch 33, the driving circuit 35 amplifies the FE signal output from the phase compensation circuit 18 and sends the FE signal to the focus control element 36. In this structure, when the focus servo system is in the closed state, the focus control element 36 is driven so that the light beam is always focused on a prescribed position of the disk. In addition, an output signal from the chopping wave generator 42 is also input to the switch 33. Further, the FE signal is also input to the logic circuit 40 through the comparator 41. The logic circuit 40

controls the opening and closing operation of the switch 33.

[0008]

The linear motor 19 moves the focusing lens 5, the focus control element 36, the polarization beam splitter 3 and the like in the direction transverse to the tracks on the disk 7, and is normally operated when a focal point of the light beam is moved to a prescribed track.

[0009]

On the other hand, the light beam 15 split by the split mirror 10 is input to the two-element photodetector 16 in the tracking servo system. The photodetector 16 has two light responsive parts C and D, and a difference output signal between output signals from the respective light responsive parts C and D becomes a track error signal (TE signal) for controlling the light beam on the disk 7 to correctly scan the tracks. Since the present invention does not directly relate to the tracking servo, detailed description is omitted here and necessary description is made in a part of embodiments.

[0010]

In the recording/reproducing apparatus with the focus servo system having the above-mentioned structure, the focus servo is performed as described in the following.

[0011]

Initially, the disk 7 is rotated by the disk motor 6. When a prescribed rotating speed is reached, the switch 33 selects

the chopping wave generator 42, and the focus control element 36 is driven in response to a signal from the chopping wave generator 42, whereby the focusing lens 5 is moved up and down, i.e., in the direction perpendicular to a recording face of the disk 7. Therefore, the focal point of the light beam on the disk 7 is moved up and down. At this time, an S-shaped FE signal (hereinafter referred to as S signal) which appears when the focal point of the light beam passes through the recording face is detected by the comparator 41. By the detection of the S signal, the logic circuit 40 can know whether the focal point of the light beam is positioned in the vicinity of the recording face or not. When the focal point is positioned in the vicinity of the recording face, the logic circuit 40 controls the switch 33 to select the phase compensation circuit 18. In this way, the focus servo loop is closed, and the focus servo (focus lead-in) is performed so that the light beam is focused on a prescribed optimum target position.

[0012]

The focus lead-in operation will be described with reference to figures 17, 18, and 19. Figure 17 illustrates a waveform of a focusing lens driving signal and a waveform of S signals appearing in an FE signal at the focus lead-in. Figure 18 illustrates a waveform for explaining the relationship between the focus lead-in level and the S signals which appear in the FE signal at a protection film at the surface of the disk 7 and

at a recording film when the focusing lens 5 approaches and goes away from the disk 7. Figure 19 is a simple flowchart showing a fundamental focus lead-in procedure in the focus servo system.

[0013]

As shown in figure 19, when the recording/reproducing apparatus is turned on, the disk motor 6 is turned on and the disk 7 is rotated in step S21. When the disk 7 reaches a prescribed rotating speed, the light source 1 is turned on and for example, the semiconductor laser emits light in step S22. Subsequently, the linear motor 19 is driven to move the focusing lens 5 toward the inner circumference of the disk 7 in step S23. When the above-mentioned initial operation is ended, the focus lead-in operation is started.

[0014]

First, as shown in figure 17, the focusing lens 5 is moved down away from the disk 7 in response to an output signal from the chopping wave generator 42 in step S24. Then, the focusing lens 5 is moved up toward the disk 7 in step S25. While repeating the up and down movement of the focusing lens 5, it is detected that the S signal reaches a prescribed lead-in level in step S26. After the prescribed lead-in level is reached, the logic circuit 40 controls the switch 33 to select the phase compensation circuit 18, and the up and down movement of the focusing lens 5 is stopped in step S27. Then in step S28, the focus servo system is turned on, the focus lead-in operation

is ended, and the focus servo is started.

[0015]

The detection level (lead-in level) of the comparator 41 for the focus lead-in is normalized by the amplitudes of the S signals which are output due to the reflection at the recording film of the disk 7 and the reflection at the protection film, respectively. As shown in figure 18, the lead-in level is set within a linear interval that is larger than the peak of the S signal at the protection film and between the peak of the S signal at the recording film and the zero level.

[0016]

[Problems to be solved by the Invention]

In this way, the focus servo lead-in operation is realized in the prior art focus servo system.

[0017]

When the prior art lead-in process is applied to large capacity disks having two or more recording/reproducing faces on one side as shown in figure 5, an S signal appears at every passing of the focal point of the light beam through each recording/reproducing face, so that the S signals as many as the recording/reproducing faces appear when the focusing lens is moved up and down during the focus lead-in operation. For example, in a dual-layer disk, as shown in figure 6, in addition to a small S signal at the protection film, a two-periodic S signal appears on each recording/reproducing face. Therefore,

in the prior art focus servo system, when the S signal at the surface protection film is detected by mistake, the focus servo is turned on at that part and the focus lead-in ends in a failure. Likewise, when the focus servo is turned on at the two-periodic S signal on the recording/reproducing face, it cannot be detected that the lead-in is performed on which one of the two faces. Therefore, it is very difficult to reproduce information by certainly selecting one of the two layers, i.e., an upper face or a lower face, and performing focus servo and tracking servo on the selected face.

[0018]

Further, in an optical head including a hologram element 106 as shown in figure 1 in order to realize compatibility with a CD, images are formed on two focuses 107a and 107b shown in figure 1. Owing to these two beams, at least six S signals appear in the FE signal at each UP or DOWN of the focusing lens 5 during the lead-in operation as shown in figure 6. Further, when the surface deflection of the disk is large, the S signals interfere with each other and becomes nonlinear. Therefore, it is almost impossible to learn the lead-in level by measuring the amplitudes of the S signals and perform focus lead-in operation by certainly detecting the face on which the focus lead-in should be performed.

[0019]

Furthermore, the eccentricity, the focus offset value, the

tracking offset value, the focus gain value, the tracking gain value, and the focus error during the seeking vary for each recording/reproducing face. Therefore, even though these correction values are appropriately set for one face, considerable errors occur on another recording/reproducing face, whereby the focus servo and the tracking servo become unstable. In addition, the focus error becomes significant during the track seeking, so that stable seeking cannot be performed.

[0020]

The present invention is made to solve the above-mentioned problems in the prior art. An object of the present invention is to provide a high-speed and stable method for controlling the focus servo lead-in even when a dual-layer disk or a multiple-layer disk is used or when a head for irradiating the disk with a light beam has two focuses. In addition, another object of the present invention is to provide a highly reliable optical recording/reproducing apparatus which can secure sufficient performances of focusing, tracking, and track seeking for each layer, and which is suited for a large capacity dual-layer or multiple-layer disk.

[0021]

[Measures to Solve the Problems]

According a first aspect of the present invention, a focus servo system comprising: focusing means for focusing a light beam on a recording medium having plural recording/reproducing

faces which are laminated; moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium face; focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium; initial lead-in face detecting means for driving the moving means at the starting or resuming of the apparatus, and detecting a recording/reproducing face of the recording medium which is reached first by the focal point of the light beam when the focusing means goes away from the recording medium after approaching the recording medium or when the focusing means approaches the recording medium after going away from the recording medium; and focus control means for driving the moving means in response to an output signal from the focusing state detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium, said focus control means being driven in response to a signal from the initial lead-in face detecting means. Therefore, the above object is achieved.

[0022]

According to a second aspect of the present invention, a focus servo system comprising: focusing means for focusing a light beam on a recording medium having plural recording/reproducing faces which are laminated; moving means for moving a focal point of the light beam focused by the focusing means

in a direction substantially perpendicular to the recording medium face; focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium; focus control means for driving the moving means in response to an output signal from the focusing state detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium; and focus jumping means for driving the moving means by switching the state of the focus control means from an operation state into a non-operation state and moving the focal point of the light beam from a recording/ reproducing face to another recording/reproducing face on the recording medium, said focus jumping means comprising: accelerating/decelerating means for accelerating/decelerating moving speed of the focal point of the light beam on the basis of the signal from the focusing state detecting means; and jumping lead-in means for detecting a recording/reproducing face of a moving destination on the basis of a prescribed level reached by the signal from the focusing state detecting means, and re-operate the focus control means. Therefore, the above object is achieved.

[0023]

According to a third aspect of the present invention, an optical recording/reproducing apparatus comprising: focusing means for focusing a light beam on a recording medium having plural recording/reproducing faces which are laminated; first

moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium; second moving means for moving the focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium and the track; focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium; track error detecting means for generating a signal corresponding to a positional relationship between the focal point of the light beam on the recording medium and the track; focus control means for driving the first moving means in response to an output signal from the focusing state detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium; tracking control means for driving the second moving means in response to an output signal from the track error detecting means and controlling the light beam so that the focal point of the light beam scans the track correctly on the recording medium; and focus jumping means for driving the moving means by switching the state of the focus control means from an operation state into a non-operation state and moving the focal point of the light beam from a recording/reproducing face to another recording/reproducing face on the recording medium; and further comprising: learning means for driving the focus control means and the tracking control means on each recording/

reproducing face of the recording medium at starting of the apparatus, and learning and selecting a set value which is necessary in each control means; and storing means for storing the set value. Therefore, the above object is achieved.

[0024]

According to a fourth aspect of the present invention, a focus servo system comprising: focusing means for focusing a light beam on a recording medium having a track on which a concave signal and a convex signal in a pit part and a mirror part are recorded in advance; a first signal detecting means for detecting a signal increasing when the light beam focused by the focusing means is shifted toward a positive direction with relative to the recording medium; a second signal detecting means for detecting a signal increasing when the light beam focused by the focusing means is shifted toward a negative direction with relative to the recording medium; first and second peak hold means for peak holding parts corresponding to mirror parts of the first and second signal detecting means; first focusing state detecting means for generating a signal corresponding to a focusing state of the light beam on the recording medium by the first and second peak hold signals; moving means for moving a focal point of the light beam focused by the focusing means in a direction substantially perpendicular to the recording medium face; and focus control means for driving the moving means in response to an output signal from the first focusing state

detecting means and controlling the light beam so that the light beam is focused at an approximately fixed position on the recording medium. Therefore, the above object is achieved.

[0025]

[Functions]

A focus servo system of the present invention, at the starting or resuming of the apparatus, on a recording medium having two or more recording/reproducing faces, drives a focusing means up and down toward the recording medium by a moving means, and performs lead-in to operate a focus servo by detecting a recording/reproducing face which is reached first by a focal point of a light beam when the focusing means goes away after approaching the recording medium or the focusing means comes close after going away from the recording medium, i.e., that an S signal appearing first in an FE signal has a prescribed level. Therefore, the focus servo system always leads the focus servo in the highest recording/reproducing face or the lowest recording/reproducing face of the recording medium, which enables to move the light beam to respective recording/reproducing faces on the basis of the led-in recording/reproducing faces.

[0026]

Further, moving to each recording/reproducing face is realized by a focus jumping means. The focus jumping means switches the state of a focus control means from an operation

state to a non-operation state, applies an accelerating signal to the moving means, detects a position of the focal point of the light beam according to the level of the S signal on the FE signal which is a signal output from a focusing state detecting means, switches a signal to be added to the moving means from an accelerating signal to an decelerating signal, and drives the focus control means when it is detected that the present position is in the vicinity of the recording/reproducing face of the target moving destination. Therefore, it is possible to securely move the focal point to the adjacent target recording/reproducing face.

[0027]

At this time, before the focus servo lead-in is performed, the amplitude of the S signal appearing when the moving means is moved up and down is measured, the gain is changed to be optimum for the amplitude to be detected, and the lead-in level for the amplitude is set. Therefore, it is possible to perform the lead-in or the moving to each recording/reproducing face by the focus jumping, with high reliability.

[0028]

The optical recording/reproducing apparatus according to the present invention adds a tracking control means, a learning means and the like to the focus control means, learns the eccentricity, the offset values and the gain values in focusing and tracking on each recording/reproducing face, and when the

focal point is moved to a prescribed recording/reproducing face by the focus jumping means, selects and sets a set value corresponding to the recording/reproducing face of the moving destination. Therefore, it is possible to realize a stability of a focus servo and a tracking servo in any of the recording/reproducing faces.

[0029]

Further, the focus servo system according to the present invention holds the respective peaks of a signal of the first detecting means for detecting a signal increasing when the focal point of the light beam on the recording medium is shifted to a positive direction and a signal of the second detecting means for detecting a signal increasing when the focal point of the light beam on the recording medium is shifted to a negative direction, and drives the moving means on the basis of the difference signal of the peak held signals to control the focus servo. Therefore, it is possible to obtain the stable seeking performance by reducing the influences of a track cross to the FE signal during the seeking to reduce the focus error.

[0030]

[Embodiments]

Hereinafter, embodiments of the present invention will be described in detail with reference to the drawing. In the drawings, components having equivalent functions are shown by the same reference numbers.

[0031]

Figure 1 is a block diagram showing a structure for performing the focus servo lead-in operation by applying a DSP, according to an embodiment of the present invention.

[0032]

As shown in the figure, a recording/reproducing apparatus according to the present invention comprises a light source 108 such as a semiconductor laser, which is an optical system for irradiating a disk 101 as a recording medium with a light beam 8, a coupling lens 109, a polarization beam splitter 110, a hologram element 106, a focusing lens 105, and a disk motor 102 for rotating the disk 101 at a prescribed rotational speed. The light beam emitted from the light source 108 is collimated by the coupling lens 109. This collimated light beam is reflected by the polarization beam splitter 110, is passed through the hologram element 106, and is split into two beams. Then the two beams are focused by the focusing lens 105, forming two light beam spots so as to have two focuses 107a and 107b in the direction perpendicular to the surface of the disk. The respective light beam spots 107a and 107b irradiate the disk 101 which is rotated by the disk motor 102. These two light beams are used according to base material thickness of the disk to be equipped. For example, when the disk is a CD having a thickness of 1.2 mm, the light beam 107b is focused on the recording/reproducing face. When the disk is a high-density disk having a base material

thickness of 0.6 mm, the light beam 107a is focused on the recording/reproducing face.

[0033]

Further, the recording/reproducing apparatus according to the present invention is applicable to a one-layer disk having one reproducing face such as a conventional CD, as well as a dual-layer disk in which two recording/reproducing faces, one of which is a semi-transparent film, are bonded with a 20 ~ 60 μm adhesive film like a sandwich as shown in figure 5(a), or an N-layer disk in which several microns thick recording/reproducing films are laminated and bounded as shown in figure 5(b) (in this embodiment, N = 4).

[0034]

This recording/reproducing apparatus further includes a condenser lens 111 and a split mirror 112, both being elements for receiving a reflected light from the disk 101. The reflected light from the disk 7 passes through the focusing lens 105, the hologram element 106, the polarization beam splitter 110, and the condenser lens 111 and is split into light beams 140 and 141 in two directions by the split mirror 112. The light beams 140 and 141 are input to a focus servo system which is constituted by a DSP 129, an A/D converter 123, and a gain change circuit 121 and the like, and a tracking servo system which is constituted by the DSP 129, an A/D converter 124, and a gain change circuit 122 and the like, respectively.

[0035]

The tracking servo system comprises a two-element photodetector 116, preamplifiers 117 and 118, a differential amplifier 119, a gain change circuit 121, a DSP 129, an A/D converter 123, a driving circuit 131, and a tracking actuator 103.

[0036]

The light beam 140 split by the split mirror 112 is input to the photodetector 116. The photodetector 116 has a two light responsive parts C and D, and output signals from the respective light responsive parts C and D are amplified by the preamplifiers 117 and 118, respectively, and input to the differential amplifier 119. The differential amplifier 119 outputs a difference signal between output signals from the respective light responsive parts C and D, and this difference signal becomes a tracking error signal (TE signal) for controlling the light beam on the disk 7 to correctly scan the tracks. The method for detecting the TE signal is not restricted to a push-pull method as in the present invention. Other methods, such as a three beam method, a phase difference method and the like may be used in the present invention.

[0037]

On the other hand, the focus servo system comprises the two-element photodetector 113, the preamplifiers 114 and 115, a differential amplifier 120, a gain change circuit 122, the

DSP 129, an A/D converter 124, a driving circuit 131, and a focus actuator 104. The light beam 141 split by the split mirror 112 is input to the photodetector 113. The photodetector 113 has two light responsive parts A and B, and output signals from the respective light responsive parts A and B are amplified by the preamplifiers 114 and 115, respectively, and the amplified signals are input to the differential amplifier 120. Here, a knife edge detection method is realized by the condenser lens 111 and the split mirror 112 and an output signal from the differential amplifier 14 becomes an FE signal. The method for detecting the FE signal is not restricted to the knife edge method. Other methods, such as an astigmatic method and an SSD (Spot Sized Detection) method, may be employed in the present invention.

[0038]

The gain change circuit 122 adjusts the amplitude of the FE signal to a prescribed amplitude (gain) in response to the amount of the light beam corresponding to the reflectivity or the like of the disk 101. Thereafter, the FE signal is converted to a digital signal by the A/D converter 124 and input to the DSP 129.

[0039]

Figure 2 is a block diagram illustrating the focus servo system and the focus lead-in system within the DSP 129 in detail. Hereinafter, the structure will be described with reference to

figures 1 and 2. The DSP 129 constitutes a digital control system internally and comprises a switch 201, a phase compensating filter 202, a gain changeable module 203, a switch 204, an S signal detecting part 205, a level judge part 206, a waveform generating part 207, and a hold part 208.

[0040]

The FE signal digitally converted by the A/D converter 123 is sent through the switch 201 which opens and closes a loop of the focus servo system to the phase compensating filter 202 comprising an adder, a multiplier, and a delay element. The phase delay of the FE signal in the focus servo system is compensated by the phase compensating filter. Thereafter, the FE signal is sent through the gain changeable module 203 which switches a loop gain of the focus servo system to the switch 204. The switch 204 opens and closes the loop of the servo system. Further, during the focus servo lead-in, the switch 204 applies an UP/DOWN signal for detecting a recording/reproducing face of the disk 101 by moving the focusing lens up and down to the driving circuit 131 for driving the focus actuator. The FE signal which passes through the switch 204 is converted to an analog signal by a D/A converter 209 and input to the driving circuit 131. In the driving circuit 131, the focus control signal is subjected to appropriate current amplification and level change, whereby the focus actuator 104 is driven. In this way, the focus actuator 104 is driven so that the light beam

is always focused on a prescribed position of the disk 101.

[0041]

At the focus lead-in (when the focus servo is led in), a chopping wave shaped UP/DOWN signal is output by the waveform generating part 207, the B-C line of the switch 204 is turned on, the focus actuator 104 is driven by the D/A converter 209 and the driving circuit 131, and the focusing lens 105 is moved upward toward the disk 101 and downward away from the disk 101.

[0042]

Figure 6 shows waveforms illustrating an FE signal, a driving signal, and relative positions of a lens and a disk having two recording/reproducing faces (hereinafter referred to as dual-layer disk) as shown in figure 5(a) when the lens approaches and goes away from the disk. As shown in figure 6, double S-shaped signals (hereinafter referred to as S signal) appear on the FE signal which is obtained from the differential amplifier 120, or the gain changeable module 122 and the A/D converter 124. Learning is performed so that the amplitudes of the S signals become constant, a prescribed level in the vicinity of the zero cross point (focus point) is detected, and the focus servo lead-in is performed.

[0043]

Describing further with reference to figure 2, the FE signal after the A/D conversion branches in the DSP 129 and realizes a focus lead-in learning operation. The disk 101 is rotated,

the semiconductor 108 emits light, and the waveform generating part 207 outputs an UP/DOWN signal, thereby moving focusing lens 105 toward the disk or away from the disk. At this time, in the S signal detecting part 205, an amplitude of an S signal which appears on the FE signal branching after the A/D conversion during the close and away movement of the focusing lens is measured. When the measured amplitude is smaller than a prescribed amplitude, the gain change circuit 122 is controlled to reduce the gain. When the measured amplitude is larger than the prescribed amplitude, the gain change circuit 122 is controlled to increase the gain. Therefore, it is possible to make the amplitude of the S signal constant by the output after the A/D converter 124. The FE signal including the S signal which is controlled by the S signal detecting part 205 and the gain change circuit 122 to have the prescribed amplitude is input to the level judge part 206. In the level judge part, the input FE signal is compared with a prescribed amplitude level (lead-in level). After the detection of the lead-in level, the switch 201 is turned on and the A-C line of the switch 204 is turned on to close the focus servo loop, whereby the focus lead-in operation is achieved.

[0044]

The waveform generating part 207 generates an accelerating pulse and a decelerating pulse when the light beam spot moves from the first layer to the second layer, or from the second

layer to the first layer in a dual-layer disk. The accelerating pulse and the decelerating pulse will be described later.

[0045]

Hereinafter, a focus lead-in method in a dual-layer disk according to a first embodiment of the present invention will be described in detail. As a first example of the focus lead-in method, a method for performing the focus lead-in operation in a dual-layer disk comprising a thin base material (for example, 0.6mm) with a light beam 105a will be described in this embodiment.

[0046]

Figure 7 shows a waveform illustrating the relationship between the FE signal and the UP/DOWN signal, i.e., a focus driving signal which is output from the waveform generating part 207 at the actual focus lead-in operation. In the figure, the same alphabets as those in figure 6 designate the same positions. Figure 8 is a flowchart for explaining the focus learning lead-in process which is realized by the DSP 129.

[0047]

When the recording/reproducing apparatus is turned on, the motor 102 is rotated. When a prescribed rotating speed is reached in the disk 101, the semiconductor laser emits light and the focus lead-in operation starts.

[0048]

In step 1 in figure 8, the waveform generating part 207

generates a chopping wave signal which moves the lens up and down, and the chopping wave signal is sent through the switch 204 and the D/A converter 209 to the driving circuit 3. The driving circuit 3 drives the focus actuator 36 so that the focusing lens 5 moves upward to the point H nearest to the disk as shown in figures 6 and 7. At this time, the focal point of the light beam 105a is positioned above the recording/reproducing face L1 of the second layer which is a upper layer of the disk.

[0049]

When the focusing lens 105 reaches the nearest point H, the focusing lens 105 is then moved downward away from the disk 101, and an FE signal is sampled at that time in steps S2 and S3. As shown in figure 7, when the focusing lens 105 is gradually moved downward, the focal point of the light beam 107a which is nearer to the lens reaches the recording/reproducing face of the second layer L1 of the disk at a point I. An S signal Q2 corresponding to the L1 face appears in the vicinity of the point I.

[0050]

There are various methods for measuring an amplitude of the S signal Q2. For example, the FE signal is continuously sampled, a maximum value or a minimum value is obtained by comparing the respective sampled values of the FE signal, and an amplitude of the S signal Q2 is easily obtained from the maximum value

or the minimum value. Further, in order to prevent the precision of the sampled FE signal from being degraded by circuit noise, or noise due to an address part preformatted on the disk or due to scratches on the disk, the sampled FE signal is passed through a digital low-pass filter which is constituted by a software processing of the DSP 129, and a maximum value or a minimum value is obtained from the FE signal which has been passed through the digital filter. Thereby, the amplitude can be measured with high precision (step S4).

[0051]

When the measurement of the amplitude of the S signal Q2 is completed, the lens is further moved downward and the FE signal is sampled (steps S5, S6, and S7). Since the distance between the second layer L1 and the first layer L0 is about 40 microns, immediately after the light beams spot passed through the point I of the second layer, the light beam reaches the point J of the first layer of the recording/reproducing face. An S signal Q1 corresponding to the amount of the light appears in the vicinity of the point J. The measurement of the S signal Q1 is performed in a way similar to that of the S signal Q2 in step S8.

[0052]

When the measurement of the amplitude of the S signal Q1 is completed, the lens is moved downward to a point E farthest from the disk. Meanwhile, since the focal point of the upper

light beam 107b crosses the recording/reproducing face, an S signal corresponding thereto appears in the FE signal. When the surface deflection of the disk is particularly large, the light beams 107a and 107b detect the recording/reproducing face at almost the same time, and the two S signals interfere with each other and become nonlinear. However, this portion is ignored, and the focusing lens is moved downward to reach the point A farthest from the disk (steps S10 and S11).

[0053]

When the focusing lens 105 reaches the farthest point A, the focusing lens 105 is again moved from the farthest point A toward the disk 101. Since the focal point of the upper light beams 107b crosses the recording/reproducing face first, an S signal corresponding to the focal point appears in the FE signal. When the surface deflection of the disk is particularly large, the light beams 107a and 107b detect the recording/reproducing face at almost the same time, and the two S signals interfere with each other and become nonlinear. So, it is difficult to accurately detect the recording/reproducing faces L0 and L1 with the light beam 107a. Therefore, during the upward movement of the lens, the detection of S signals is not performed and the focusing lens 105 is quickly moved up to the point H nearest to the disk again (step S12). At this time, on the basis of the amplitude of the S signal Q2 of the second layer and the amplitude of the S signal Q1 of the first layer, which are measured during

the previous downward movement of the lens, an appropriate focus gain for each layer is calculated, and a set value of the gain change circuit 122 is stored in a RAM (Random-Access Memory, not shown in the figure) in the DSP 129. Further, an amplitude of the S signal at the changed gain value is calculated, and a value equal to 10 - 30 % of the amplitude is set as a focus lead-in level. Thus calculated lead-in levels for the first layer and the second layer are also stored in the RAM in the DSP 129 similarly to the above-mentioned amplitude of the S signal (steps S13 and S14).

[0054]

Thereafter, a focus gain value and a lead-in level corresponding to the second layer L1 which is detected first by the light beam 105a when the focusing lens 105 is moved downward from the point E nearest to the disk are set in the gain changeable module 122 and the level judge part 207, respectively (steps S15 and S16). After the setting, the focusing lens 105 is moved downward, the FE signal is sampled, and the sampled FE signal is compared with the set lead-in level. When the lead-in level is reached or exceeded, it is judged that the lead-in level is detected. Then, the UP/DOWN signal is stopped to stop the downward movement of the lens. And the switch 201 is turned on and the A-C line of the switch 204 is turned on (i.e., FCON) to close the focus servo loop, whereby the focus lead-in is completed (steps S19, S20, and S21). In this way,

after the focus lead-in on the recording/reproducing face (L1) which is reached first by the focal point of the light beam, the light beam is moved toward a prescribed recording/reproducing face adjacent to the recording/reproducing face L1, and signals are recorded in or reproduced from this recording/reproducing face. The method for moving the light beam will be described later in the second embodiment.

[0055]

As a second focus lead-in method according to the embodiment, a method for leading in the focus in a disk having a conventional base material thickness (1.2 mm) and a two recording/reproducing faces with the light beam 105b as shown in figure 1 will described. Even when the disk has a laminated structure comprising four or more layers, the only difference from a dual-layer disk is that the number of the detected S signals increases by the number of the layers. Therefore, it is possible to realize the focus lead-in in a way similar to the case of the dual-layer disk. In addition, the method is easily applied to a disk having only one reproducing face such as a CD by assuming that there is no S signal of the second layer, i.e., a value of 0 is calculated and stored as data.

[0056]

The relationship between the FE signal at the focus lead-in and the UP/DOWN signal output from the waveform generating part 207 is similar to that in the above-mentioned first focus lead-in

method as shown in figure 6. Therefore, the focus lead-in method is described with reference to figure 6 and figure 9 which is a flowchart for explaining the second focus lead-in process realized by the DSP 129.

[0057]

As shown in figure 9, when the recording/reproducing apparatus is turned on, the motor 102 rotates. When a prescribed rotating speed is reached in the disk 101, the semiconductor laser 108 emits light.

[0058]

Thereafter, in step S1, the waveform generating part 207 generates a chopping wave signal which moves the lens up and down, and the chopping wave signal is sent through the switch 204 and the D/A converter 209 to the driving circuit 131. And the focus actuator 104 moves the focusing lens 105 downward to the point A farthest from the disk shown in figure 6.

[0059]

When the focusing lens 105 reaches the farthest point A, the focusing lens 105 is then moved up toward the disk 101 and an FE signal is sampled at that time, in steps S2 and S3. As shown in figure 6, when the focusing lens 105 gradually moved upward, the focal point of the upper light beam 107b which is more distant from the lens reaches the first layer L0 of the recording/reproducing face of the disk at a point C. Then, an S signal P1 corresponding to the face L0 appears in the vicinity

of the point C.

[0060]

In this case, the amplitude of the S signal P1 is measured in the following process. That is, the FE signal similar to that in the first lead-in method is continuously sampled, a maximum value or a minimum value is obtained by comparing the respective sampled values, and the amplitude of the S signal P1 is obtained from the maximum value or the minimum value.

[0061]

When the measurement of the amplitude of the S signal P1 is completed, the lens is further moved up and the FE signal is sampled (steps S5, S6, and S7). In the case of this dual-layer disk, since the distance between the first layer L1 and the first layer L0 is also about 40 microns as described above, immediately after the light beams spot passed through the point C of the first layer, the light beam reaches the point D of the second layer of the recording/reproducing face. An S signal P2 corresponding to the amount of the light appears in the vicinity of the point D. The amplitude of the S signal P2 is measured in a way similar to that of the S signal P1 in step S8.

[0062]

When the measurement of the amplitude of the S signal P1 is completed, the lens is moved downward to the point E nearest to the disk. Meanwhile, the focal point of the lower light beam 107a also crosses the recording/reproducing face, and S signals

Q1 and Q2 corresponding to the light beams appear in the FE signal. When the surface deflection of the disk is particularly large, the light beams 107a and 107b detect the recording/reproducing face at almost the same time, and the two S signals may interfere with each other and become nonlinear. Therefore, this portion is ignored, and the focusing lens is moved upward to reach the point H nearest to the disk (steps S10 and S11).

[0063]

When the focusing lens 105 reaches the nearest point H, the focusing lens 105 is again moved away from the disk 101 from the nearest point H. Since the focal point of the upper light beams 107b crosses the recording/reproducing face first, an S signal corresponding to the focal point appears in the FE signal. When the surface deflection of the disk is particularly large, the light beams 107a and 107b detect the recording/reproducing face at almost the same time, and the two S signals interfere with each other and become nonlinear. So, it is difficult to accurately detect the recording/reproducing faces L0 and L1 with the light beam 107b. Therefore, during the downward movement of the lens, the detection of S signals is not performed and the focusing lens 105 is quickly moved down to the point H farthest from the disk again (step S12). At this time, on the basis of the amplitude of the S signal P1 of the first layer and the amplitude of the S signal P2 of the second layer, which are measured during the previous upward movement of the lens,

an appropriate focus gain for each layer is calculated, and a set value of the gain change circuit 122 is stored in a RAM (not shown in the figure) in the DSP 129. Further, an amplitude of the S signal at the changed gain value is calculated, and a value which exceeds amplitudes of minute S signals resulting from the reflection at the surface of the disk (which is equal to 10 ~ 30 % of the prescribed amplitude) is set as a focus lead-in level. Thus calculated lead-in levels for the first layer and the second layer are also stored in the RAM in the DSP 129 similarly to the above-mentioned amplitude of the S signal (steps S13 and S14).

[0064]

At the same time, a focus gain value and a lead-in level corresponding to the first layer L0 which is detected first by the light beam 105b after the light beam 105b passes through the surface, when the focusing lens 105 is moved upward from the farthest point A are set in the gain changeable module 122 and the level judge part 207, respectively (steps S15 and S16). After the setting, the focusing lens 105 is moved upward, the FE signal is sampled, and the sampled FE signal is compared with the set lead-in level. When the lead-in level is reached or exceeded, it is judged that the lead-in level is detected. Then, the UP/DOWN signal is stopped to stop the upward movement of the lens. And the switch 201 is turned on and the A-C line of the switch 204 is turned on (i.e., FCON) to close the focus servo

loop, whereby the focus lead-in is completed (steps S19, S20, and S21). As similar to the first focus lead-in method, after the focus lead-in on the recording/reproducing face (L0) which is reached first by the focal point of the light beam, then the light beam is moved toward a prescribed recording/reproducing face adjacent to the recording/reproducing face L0, and signals are recorded in or reproduced from this recording/reproducing face. The method for moving the light beam will be described later in focus jumping of the second embodiment.

[0065]

By employing the first and second methods as described above, in an optical recording/reproducing apparatus according to the present invention which has two focuses corresponding to the disks of different base material thicknesses, even when dual-layer or multiple-layer disks of different base material thicknesses are loaded in the apparatus, since the detection and measurement of S signals, the gain change, and the lead-in level learning can be performed accurately by the upper and lower light beams corresponding to the respective disks, the focus can be led in the recording/reproducing face which is detected first, with high reliability.

[0066]

Next, an example of a focus jumping for moving a light beam from one recording/reproducing face to another recording/ reproducing face according to a second embodiment of the present

invention will be described with reference to figures 1 to 3, 10 and 11. Here, figure 3 is a block diagram illustrating in detail the tracking servo system in the DSP 129 shown in figure 1. Figure 10 shows waveforms of an FE signal, a positive and negative pulse signal FEJMP generated in the waveform generator and applied to the focus servo system, and a TE signal, when the focus jumping is performed from L0 to L1, and from L1 to L0. Figure 11 is a flowchart illustrating the focus jumping process realized by a DSP 122.

[0067]

When a focal point of the light beam is moved from the first layer L0 to the second layer L1, or from the second layer L1 to the first layer L2, as in above-mentioned focus lead-in process, a pulse signal FOJMP is produced in the waveform generator 207 and applied to the servo system by a software processing within the DSP 122, whereby the focal point of the light beam is moved from a recording/reproducing face to recording/reproducing face, i.e., focus jumping, is realized.

[0068]

For example, when the focus jumping from L0 to L1 is performed, initially, the switch 301 shown in figure 3 is turned off to turn off the tracking servo system (TROF) (step S1 in figure 11). Then the B-C line of the switch 204 in figure 2 is turned on to hold a focus driving signal by the hold part 208 (step S2).

[0069]

Next, an accelerating pulse A0 of a jumping pulse (FEJMP pulse) is produced in the waveform generator 207 shown in figure 2, and the accelerating pulse A0 is applied through the switch 204, the D/A 209, and the driving circuit 131 to the focus actuator 104 (step S3). The pulse width and the peak value of the applied accelerating pulse are set according to sensitivity of the focus actuator 104 and the surface deflection acceleration of the disk 101. When a prescribed pulse is applied to the focus servo system, the focusing lens 105 moves upward, i.e., toward the face L1. With the upward movement of the lens, an S signal appears in the FE signal as shown in figure 10 (left side in the figure).

[0070]

When it is detected that the S signal reaches the reference level 0, i.e., when the zero cross level of the FE signal is detected (step S4), the gain set value of the gain change circuit 122 is changed to a gain set value of the face L1 (step S5), and the focus lead-in level is set to a focus lead-in level of the face L1 by the level judge part 206 (step S6), whereby the S signal and the lead-in level of the face L1 are accurately detected. Further, a decelerating pulse produced in the waveform generator 207 is applied (step S7), as the accelerating pulse. By the decelerating pulse, a brake is applied to the focusing lens that is moving toward the face L1. So, when the

FE signal reaches the lead-in level R0 of the face L1, the moving speed of the focusing lens is almost the minimum, i.e., 0. At this time, the output of the decelerating pulse is stopped, and immediately the A-B line of the switch 204 in figure 2 is turned on to turn on the focus servo system, whereby in the vicinity of the lead-in level point R0, the focus is stably led in (steps S8 and S9). Thereafter, during the period of time from Ro to U0 in figure 10, it is confirmed that the focus is normally led in, by the TE signal or RF signal exceeding a prescribed value (steps S10 and S11). Finally, the switch 301 shown in figure 3 is turned on at point U0 in figure 10 to turn on the tracking servo system, a prescribed block address is sought, and the processing is completed (step S12).

[0071]

The gain of the FE signal that changes the amplitude of the S signal on the face L1 and the lead-in level thereat set in the steps S5 and S6 are learned during the above-mentioned focus lead-in and stored in the RAM within the DSP 122. Therefore, even when the amplitude of the S signal in the FE signal varies between different disks, apparatuses, or heads, the focus jumping can be performed stably against these variations. Further, the lead-in level at the focus jumping is calculated and set individually on the basis of the amplitude of the S signal and the focus lead-in level that are stored at the starting of the apparatus, with considering the lens moving speed during

the lead-in operation at the starting and the lens moving speed at the focus jumping, whereby the more stable focus lead-in is realized.

[0072]

For example, a maximum value or a minimum value of the amplitude of the S signal is stored in the RAM, and a level corresponding to a prescribed rate of the maximum value or the minimum value (preferably, 60 ~ 80%) is obtained as a comparator level. The maximum value of the S signal is detected by that the sampled FE signal becomes larger than the comparator level and thereafter smaller than the comparator level. Likewise, the minimum value of the S signal is detected by that the FE signal becomes smaller than the comparator level and thereafter larger than the comparator level. When the maximum value is detected in this way, the accelerating pulse is stopped and the decelerating pulse is output. When the minimum value is detected, the decelerating pulse is stopped to turn on the focus servo system. Therefore, the timing of acceleration and the timing of deceleration can be desirably changed by the comparator level. Especially, when the timing is appropriately quickened within a range of the performance of the focus actuator 104, unwanted positional deviation due to surface deflection of the disk is significantly reduced, so that the focus jumping can be performed at higher speed.

[0073]

When the focal point of the light beam moves from L1 to L0, the FE signal and the FEJMP pulse have waveforms as shown in figure 10 (right side in the figure). Also, in this case, the focus jumping can be realized by the process similar to those described above.

[0074]

As described above, the peak values of the accelerating pulse and the decelerating pulse are set by the stability of the focus jumping in the consideration of sensitivity of the focus actuator 104, surface deflection of the disk, vibration from the outside, and the like. Since the apparatus is normally set horizontally, the acceleration of the focusing lens 105 is +1G (G: gravitational acceleration) when the accelerating direction is upward. When the accelerating direction is downward, the acceleration is -1G. The peak value of the accelerating pulse A0 of the FOJMP pulse is made larger than that of the decelerating pulse B0 of the FOJMP pulse when the focusing lens moves from L0 to L1. When the focusing lens moves from L1 to L0, the peak value of the decelerating pulse B1 is made larger than that of the accelerating pulse, and the difference becomes about 2G.

[0075]

When the apparatus is a horizontally and vertically setting type, a DC component of the driving current of the focus actuator 104 after the turning-on of the focus control (FCON), i.e., a DC value at the input node of the D/A converter 204, is detected

and, according to the difference between the detected values, whether the apparatus is set horizontally or vertically is identified. According to the result, the accelerating pulse and the decelerating pulse are set at the optimum values for respective setting states.

[0076]

Further, in the first focus lead-in method mentioned above, at the starting and resuming of the apparatus, the focus lead-in is performed first on the layer L0 of the dual-layer disk, that is, the recording/reproducing face nearest to the source of the light beam. So, when this layer is similarly regarded as an initial reference, the first focus jumping direction at the starting of the apparatus is decided. More specifically, the direction in which the focus servo is led in first and moved by the first focus jumping is always the direction away from the L1 layer of the dual-layer disk, i.e., away from the source of the light beam. However, when recording/ reproducing face where the focus of the light beam is led in first is not a correctly detected face or when the focus of the light beam, which is led in a target recording/reproducing face, is undesirably jumped to another recording/reproducing face by accident, such as a shock from the outside, since there is no more recording/reproducing face in the prescribed focus jumping direction in the dual-layer disk as described above, the focus servo ends in a failure. In this case, however, the focus of

the light beam can be returned to the recording/reproducing face by resuming the apparatus. In case of a multiple-layer disk, the focus of the light beam can be moved in both directions by the focus jumping though it depends on the position of the recording/reproducing face where the focus is led in. After the focus jumping, a tracking is led in, and address information on the track is read, or the focus of the light beam is moved to a prescribed information track, and layer information on the track is read, whereby it is confirmed that the present position is incorrect. Therefore, by performing the resuming of the apparatus or the correction jumping with the address information, the focus of the light beam can be returned to a prescribed recording/reproducing face.

[0077]

Furthermore, in the second focus lead-in method, at the starting or resuming of the apparatus, the focus lead-in is performed first on the second layer L1 of the dual-layer disk, that is, the recording/reproducing face farthest from the source of the light beam. So, the direction in which the focus servo is led in first and moved by the first focus jumping is always the direction toward the first L0 layer of the dual-layer disk. i.e., toward the source of the light beam. Therefore, it is explicit to realize the focus servo by the same process as in the first focus lead-in method.

[0078]

Next, as a third embodiment of the present invention, description of an apparatus which cancels defocus during seeking and realizes stable seeking is given with reference to figures 1, 4, 13, 14 and 15. Figure 4 is a block diagram illustrating in detail a part of the optical disk apparatus for the peak hold processing of the FE signal and the focus servo in the DSP 122. Figure 13 is a cross-sectional view illustrating the positional relationship between the focusing lens 105, the light beam 107a, and the disk 101 for explaining the seeking process. Figure 14 illustrates waveforms of F+ and F- signals before and after peak hold, respectively, and waveforms of an FEENV signal which is a difference signal of the F+ and F- signals, and an FE signal, when seeking is executed in the arrow direction in figure 13. Figure 15 is a block diagram illustrating an apparatus using the astigmatic method in this embodiment.

[0079]

Because of errors in adjustment of optical elements, such as the photodetector 113, track cross modulation signal levels of the F+ and F- signals vary. Therefore, as shown in figure 14, the FE signal, which is a difference signal of the F+ and F- signals, is adversely affected by the track cross due to the variation, resulting in defocusing. Therefore, since a disturbance caused by the track cross is mixed during seeking, defocusing occurs, whereby the amplitude of the TE signal is reduced or the S/N ratio is degraded. As a result, counting of

the TE signal for detecting the position of the light beam in the track direction becomes impossible. Further, when the defocus is increased, focus skipping occurs, so that it becomes difficult for the focus to move to a target track. Therefore, high-speed and stable seeking is impossible.

[0080]

As shown in figure 1, the F+ and F- signals, which are obtained from the photodetector 113 through the preamplifiers 114 and 115 are subjected to peak hold by the peak hold circuits 125a and 125b, that is, upper side peaks (peaks on the mirror side of the disk 101) of these signals are held, whereby signals F+PH and F-PH, which are not adversely affected by the track cross during seeking, are generated as shown in figure 14. The FEENV signal shown in figure 14 is obtained by measuring a difference between these two signals F+PH and F-PH by the differential amplifier 126.

[0081]

This FEENV signal is put in the changeable module 127, wherein an optimum gain is set for the FEENV signal. Then, the FEENV signal is sent through the A/D converter 128 to the DSC 129. Normally, the focus servo, the focus lead-in, and the focus jumping conventionally performed by the FE signal on the basis of the input FEENV signal can be realized by the aforementioned procedure. However, when influences by the track cross that appear in the FE signal are quite large and a focus jumping needs

sufficient response, a switch 401 operated by a software processing is provided after A/D converters 124 and 128 as shown in figure 4, and the B-C line of the switch 401 is turned on, whereby the input becomes the FEENV signal only during the seeking.

[0082]

Although the knife edge method is employed for detecting the FE signal, other detection methods may be employed in this embodiment. Especially in the case that the astigmatic method is employed for detecting the FE signal as shown in figure 15, since there is a tendency for the track cross to increase the influence, the effect of the FE detection using the astigmatic method is significant.

[0083]

Finally, a starting process of a multiple-layer disk according to a fourth embodiment of the present invention is described with reference to figure 16 by employing a dual-layer disk as an example, where the dual-layer disk is loaded in the recording/reproducing apparatus and reproduced by the lower light beam 107a. Figure 16 is a flowchart showing the process from starting of a disk motor to a responsible state (stand-by state) thereof.

[0084]

When the apparatus is turned on and the dual-layer disk is loaded in the apparatus, the disk motor 102 is rotated at a

prescribed speed (DMON) in step S1. Next, in step S2, the semiconductor laser 108 is oscillated (LDON), and the focus of the lower light beam 107a is led in the second layer L1 of the dual-layer disk first by the aforementioned operation. In the state where the focus is led in the second layer L1, a maximum point and a minimum point of a sine wave shaped track cross signal appears on the TE signal due to a decentration are detected to obtain a tracking offset value (asymmentry), and correction value TOF1 is calculated and stored (steps S3 and S4). On the basis of the values, a switch 304 in figure 3 is turned on to turn on the tracking servo (step S5).

[0085]

After the tracking servo is turned on, the TE signal after a switch 301 is captured at a prescribed period (for example, 16 points per 1 rotation) on the basis of a FG pulse from a FG generator 132 mounted on a motor 102, and an average of N rotations is taken and stored in a decentration memory 306 constituted by a RAM in the DSP 129. After the storage, TM1 values in the decentration memory 306 are successively output in timing on the basis of the FG pulse, and added to a tracking servo system in a composing circuit 304 to be subjected to feedforward compensation (step S6). Next, jitters or amplitudes of RF signals are measured in the DSP 122 (input lines of the RF signals or jitter signals are not shown in the figure), and a focus offset value is calculated so that the jitter becomes

appropriately minimum and the amplitude becomes appropriately maximum and stored in the RAM (step S7). A disturbance is added to the focus servo system and the tracking servo system by a software processing in the DSP 129, the loop transfer function signals are detected, a gain correction value FOG1 of the focus and a gain correction value TRG1 of the tracking are calculated by obtaining the loop transfer function signals, and stored in the RAM (step S8). After calculating and storing learning values of the servo system in the face L1, the focal point is moved to the first layer L0 by the aforementioned focus jumping FOJMP (step S9). After moving, with keeping the tracking servo turning off (step 10), a TE offset value TOF0 is calculated in the face L0. In the same way as the second layer L1, the tracking servo is turned on with reference to the TE offset value TOF0 (step S12), and the decentration correction value TM0 is obtained on the basis of the FG pulse and the TE signal from a disk motor 102. Thereafter, in the same way as the face L1, an F0 offset value FO0, and an F0 gain value FOG0 and TRG0 are calculated and stored separately in the RAM as values for the face L0 (steps S14 and S15). As described above, after the respective learning values of the faces L0 and L1 are calculated, a prescribed track of a target layer is sought by a system demand (step S16). In this case, when the focal point moves from one layer to another layer by the focus jumping, stable focus performance and stable tracking performance can be secured in any of layers by judging

whether a target layer is the face L0 or L1 according to the information as to which of the layers the focal point moves, and setting a stored value of the RAM corresponding to each layer in a prescribed position of the focus servo system or the tracking servo system (steps S17, S18, and S19).

[0086]

While the description of this embodiment is given by employing a dual-layer disk as an example, this method can be easily applied to a disk having two or more layers by securing the RAM in the DSP where a learning value of respective layer is stored.

[0087]

Further, while the focus lead-in described by employing the first embodiment where the focus servo is first led in the face L1, it may be applied to the second embodiment where the focus servo is first led in the face L0.

[0088]

As described above, this embodiment can be applied to a recordable/reproducible multiple-layer disk and a reproducing-only multiple-layer disk where a signal is recorded in advance, and any of apparatuses which can record or reproduce those multiple-layer disks.

[0089]

[Effect of the Invention]

As described above, according to the control system and

control method of the recording/reproducing apparatus of the present invention, the learning of the amplitude of the S signal in case of a dual-layer disk or multiple-layer disk, the lead-in using the learning value, and the focus jumping are realized, and a stable performance can be obtained. Further, defocus with the track cross during the seeking is reduced by holding the peak of the focus signals and generating a focus error signal and a stable seeking is realized. Therefore, a seamless reproducing or a high-speed recording/reproducing by a small memory is possible.

[0090]

Further, in each recording/reproducing face, the offset value, the gain value, and the eccentricity are learned, the correction value thereof is calculated, and the learning value corresponding to a layer is switched at every passing through the layer. Therefore, a stable focus servo and tracking servo performance in any of layers is realized, whereby a highly reliable apparatus corresponding to a large capacity multiple-disk is provided.

[Brief description of the Drawings]

[Figure 1]

A block diagram illustrates a structure of a focus servo system and an optical recording/reproducing apparatus of the present invention.

[Figure 2]

A block diagram illustrates in detail a focus servo and a focus lead-in section.

[Figure 3]

A block diagram illustrates in detail a tracking servo and an eccentricity correction section.

[Figure 4]

A block diagram illustrates in detail a focus servo peak hold section and a servo section thereof.

[Figure 5]

A model illustrates a cross-section of a dual layer and a multiple-layer disk of the present invention.

[Figure 6]

A diagram of waveforms shows a lens driving signal and an FE signal explaining the focus servo lead-in operation, and a diagram illustrating the position of the focus lens.

[Figure 7]

A diagram of waveforms shows a lens driving signal and an FE signal explaining the focus lead-in.

[Figure 8]

A flowchart shows a focus lead-in operation according to the first embodiment of the present invention.

[Figure 9]

A flowchart shows a focus lead-in operation according to the second embodiment of the present invention.

[Figure 10]

A diagram shows waveforms of an FE signal, a lens driving signal, and a TE signal when a focus jumping is performed.

[Figure 11]

A flowchart shows a focus jumping process.

[Figure 12]

A model explains a seeking for a dual-layer disk.

[Figure 13]

A diagram of waveforms illustrates F+ and F- during of F+PH and F-PH produced by peak hold of F+ and F-, Fe as a difference of F+ and F- and FEENV as a difference of F+PH and F-PH.

[Figure 14]

A block diagram illustrates a circuit block in detecting an FE signal by an astigmatic method.

[Figure 15]

A flowchart illustrates a starting process of the optical recording/reproducing apparatus loading a dual-layer disk.

[Figure 16]

A block diagram illustrates a structure of a prior art focus servo system.

[Figure 17]

A diagram of waveforms explains a prior art focus lead-in operation.

[Figure 18]

A diagram of waveforms explains a prior art focus lead-in operation.

[Figure 19]

A flowchart illustrates a prior art focus lead-in operation.

[Description of the Reference Numerals]

6...disk motor

7...disk

8...light beam

12...photodetector

14...differential amplifier

17...gain change circuit

19...linear motor

20...micro processor

21...core

22...port

23...phase compensation circuit

24...S signal detecting part

25...UP/DOWN part

26...motor control

27...laser control part

33...switch

34...linear motor control circuit

35...driving circuit

36...focus actuator

37...motor control circuit

38...laser driving circuit

101...disk

102...disk motor

103...tracking actuator

104...focus actuator

105...focusing lens

106...hologram lens

107...focal point

108...semiconductor laser

109...coupling lens

110...polarization beam splitter

111...condenser lens

112...split mirror

113...photodetector

114...preamplifier

115...preamplifier

116...photodetector

117...preamplifier

118...preamplifier

119...differential amplifier

120... differential amplifier

121...gain changeable module

122...gain changeable module

123...A/D converter

124...A/D converter

125...peak hold circuit

126...differential amplifier

127...gain changeable module

128...A/D converter

129...DSP

130...driving circuit

131...driving circuit

132...FG generator

201...switch

202...phase compensating filter

203...gain changeable module

204...switch

205...S signal detecting part

206...level judge part

207...waveform generating part

208...hold part

209...D/A converter

301...switch

302...phase compensating filter

303...gain changeable module

304...composing circuit

305...switch

306...decentration memory

307...JMP pulse generating part

308...hold part

401... switch

[Name of the Document] Abstract

[Summary]

[Object] To provide a control system which can realize focus servo lead-in in a dual-layer or multiple-layer disk having plural recording/reproducing faces at high speed with high reliability.

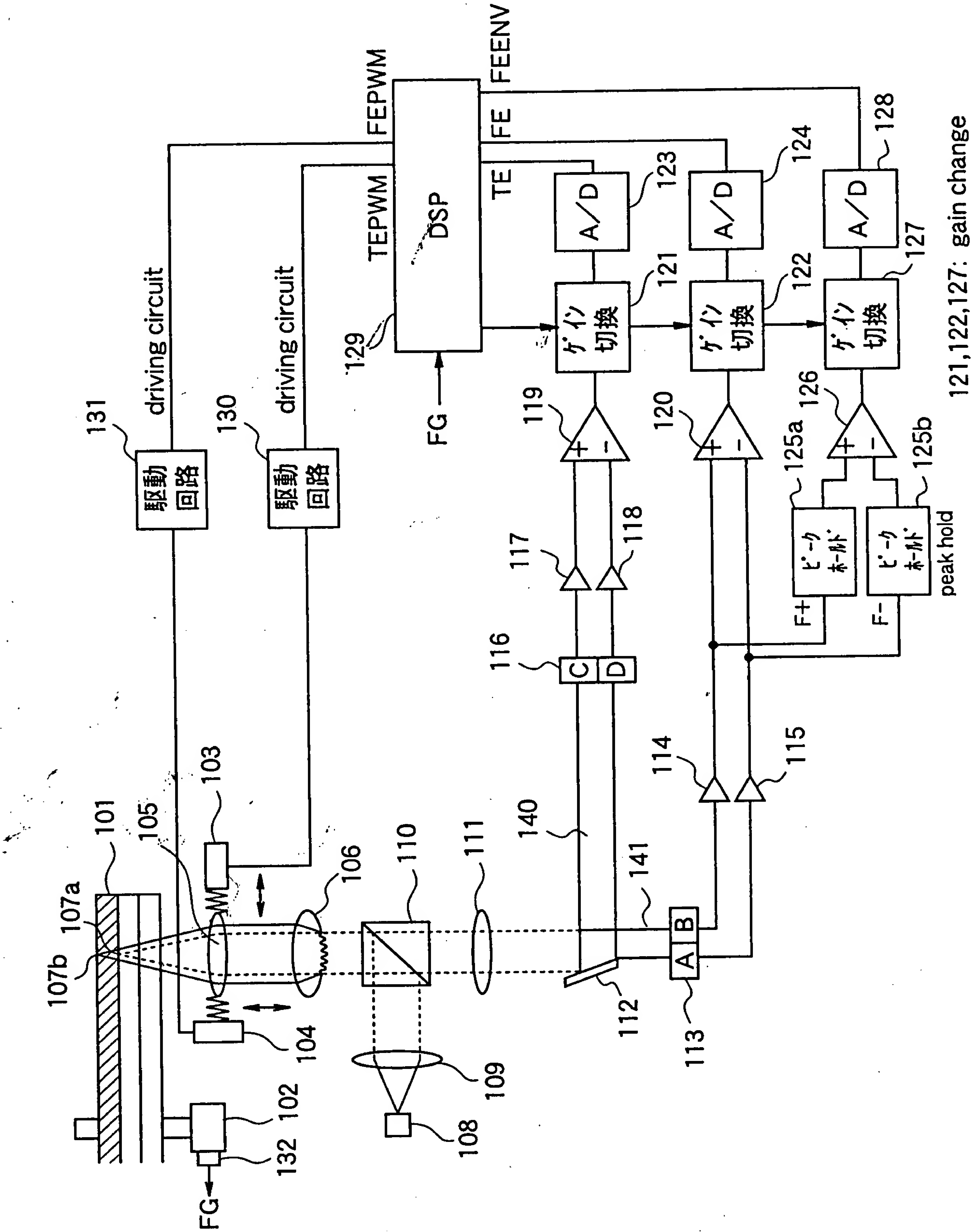
[Construction] At the starting or resuming of an apparatus, when a focusing lens goes away from the disk after approaching the disk or approaches the disk after going away from the disk, an amplitude of an S signal appearing in an FE signal at every passing of a focal point of a light beam through each recording/reproducing face is measured, a gain of a focus detection system is changed so that the S signal has a prescribed amplitude, and an optimum focus lead-in level is set. Then, when the focusing lens goes away from the disk from a highest point or approaches the disk from a lowest point, the focus servo is performed on a recording/ reproducing face which is reached first by the focal point of the light beam and the focus lead-in is completed. Thereafter, the focus servo is temporarily stopped, the focusing lens is accelerated/decelerated on the basis of the level of the FE signal and the lead-in level set on each recording/reproducing face, and the focusing lens is moved toward the next recording/reproducing face.

[Selected Figure] Figure 1

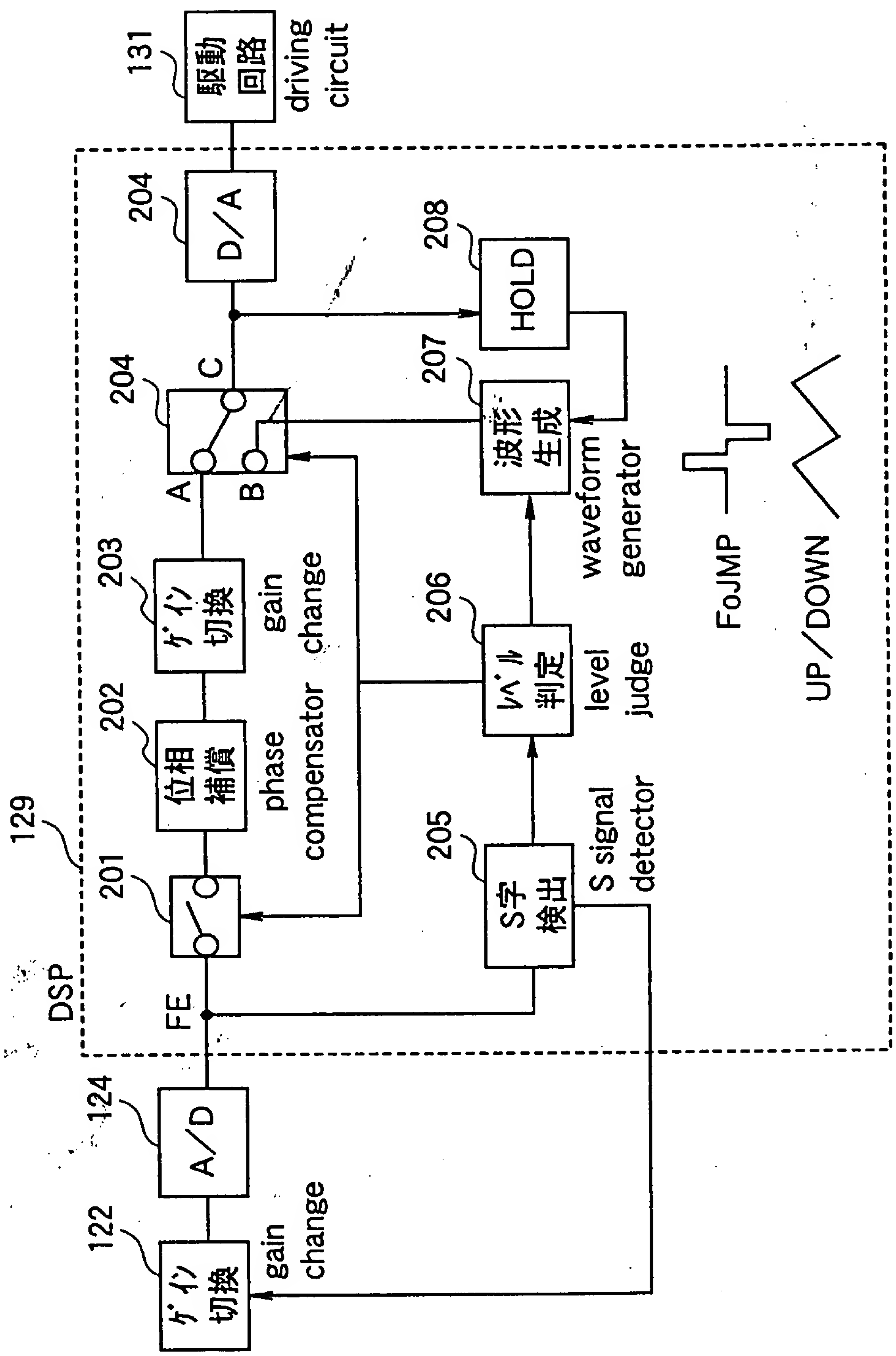
Name of Document

【書類名】　図　面　Drawing

【図1】 Figure 1

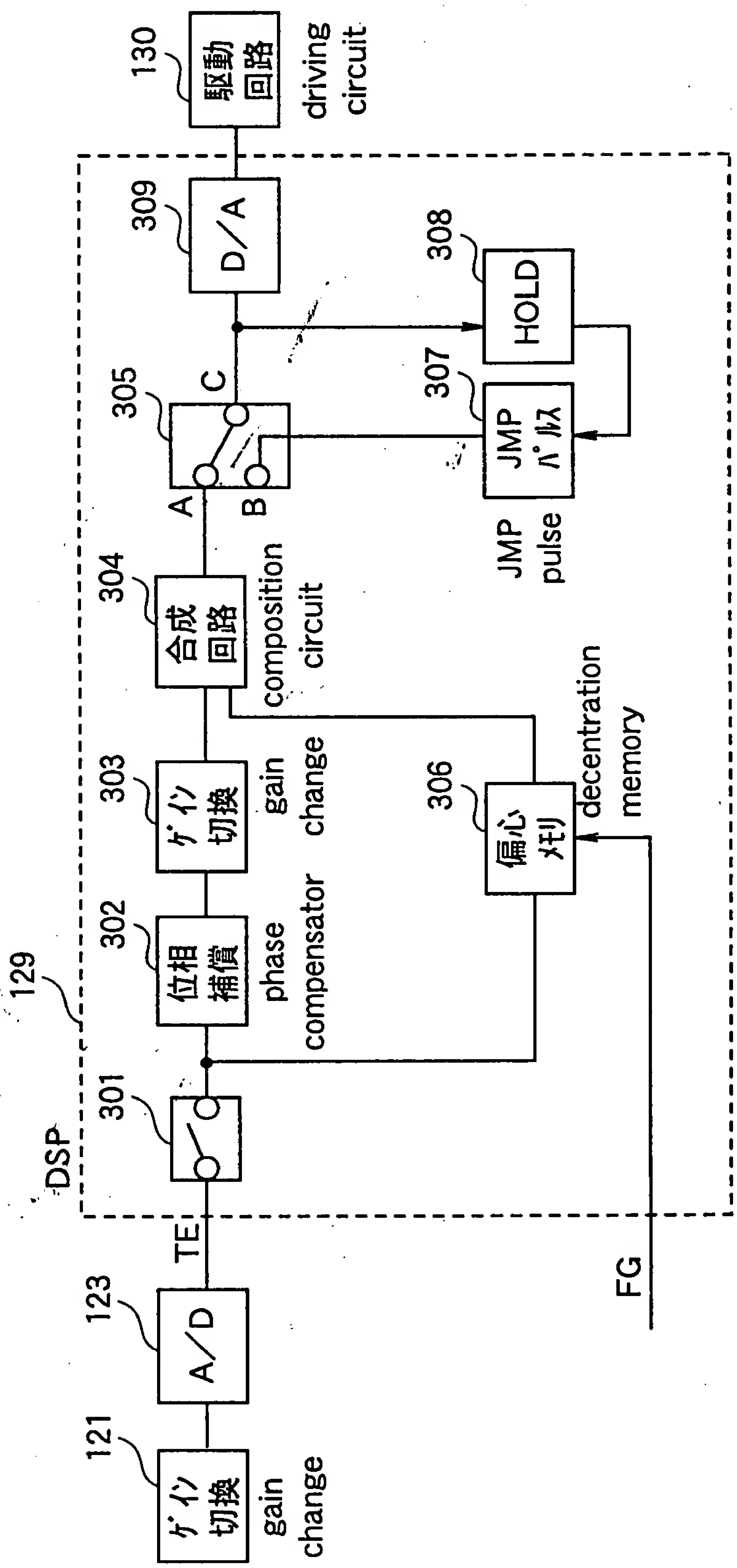


【図2】 Figure 2



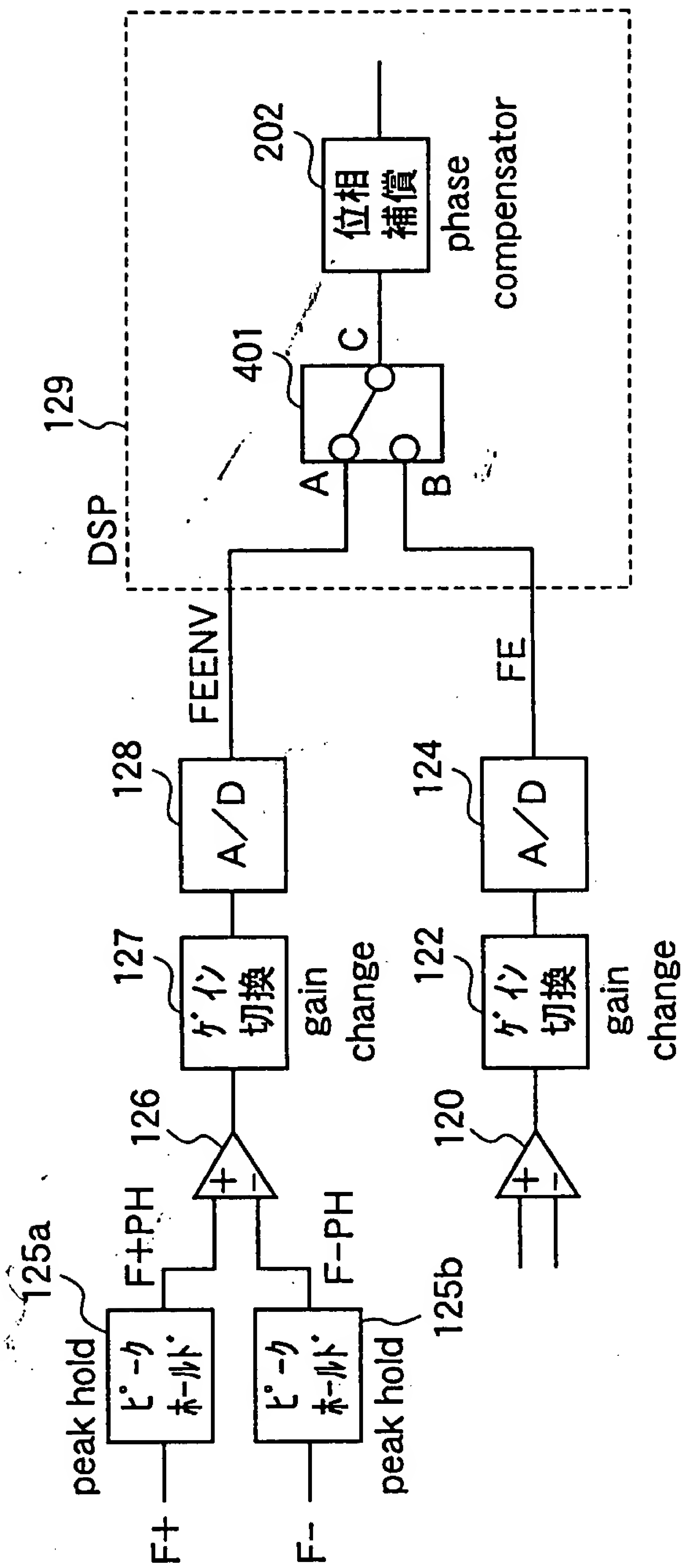
131
駆動回路
driving circuit
204
D/A
208
HOLD
204
C
207
波形生成
waveform generator
A
B
203
ｹﾞｲﾝ切換
gain change
202
位相補償
phase compensator
206
ﾚﾍﾞﾙ判定
level judge
FoJMP
UP/DOWN
129
201
205
S字検出
S signal detector
DSP
FE
124
A/D
122
ｹﾞｲﾝ切換
gain change

【図3】 Figure 3



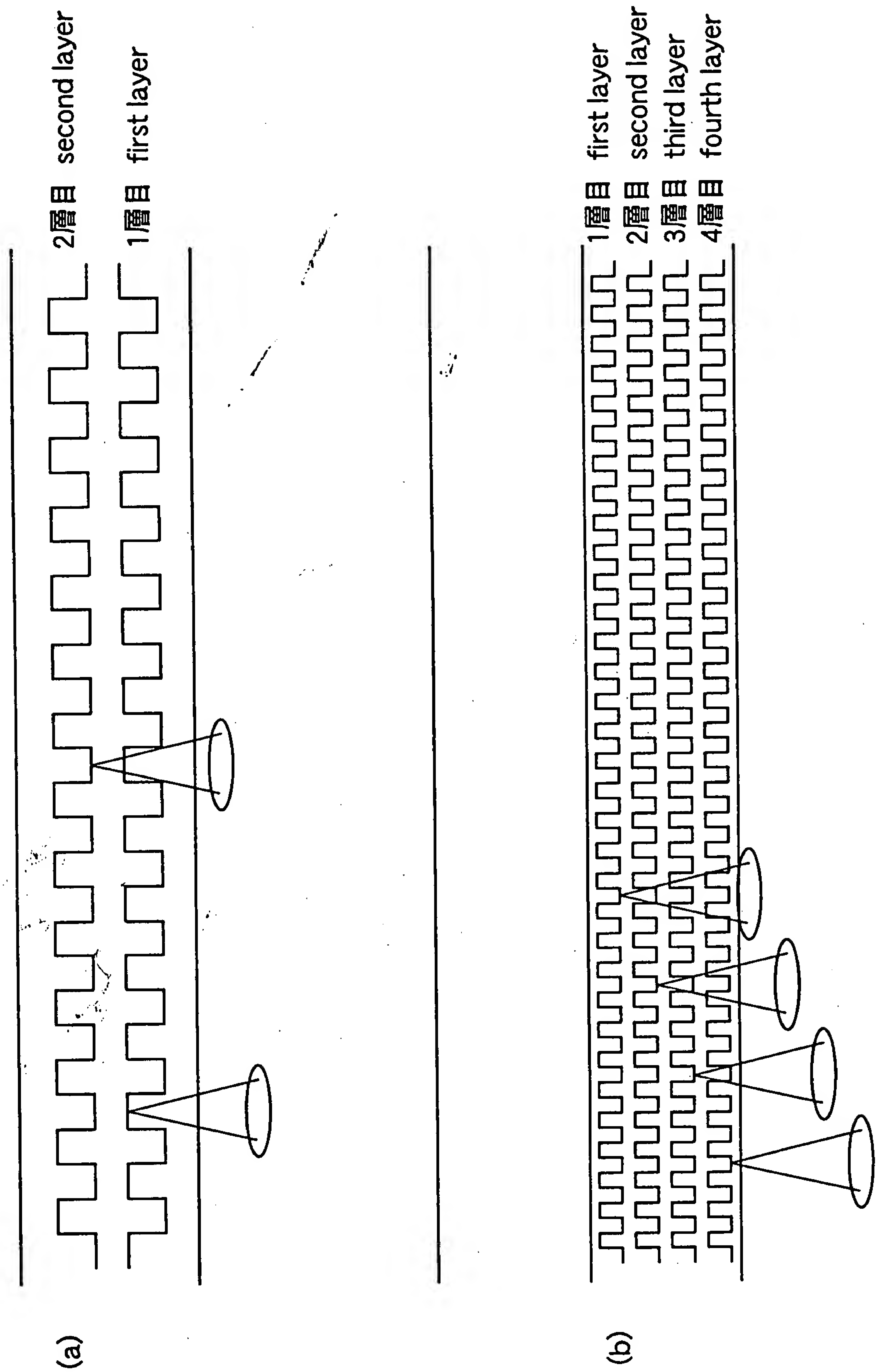
130
駆動回路
driving circuit
309
D/A
308
HOLD
307
JMPパルス
JMP pulse
305
A
B
C
304
合成回路
composition circuit
303
ゲイン切換
gain change
306
偏心メモリ
decentration memory
302
位相補償
phase compensator
129
301
DSP
TE
FG
123
A/D
121
ゲイン切換
gain change

【図4】 Figure 4

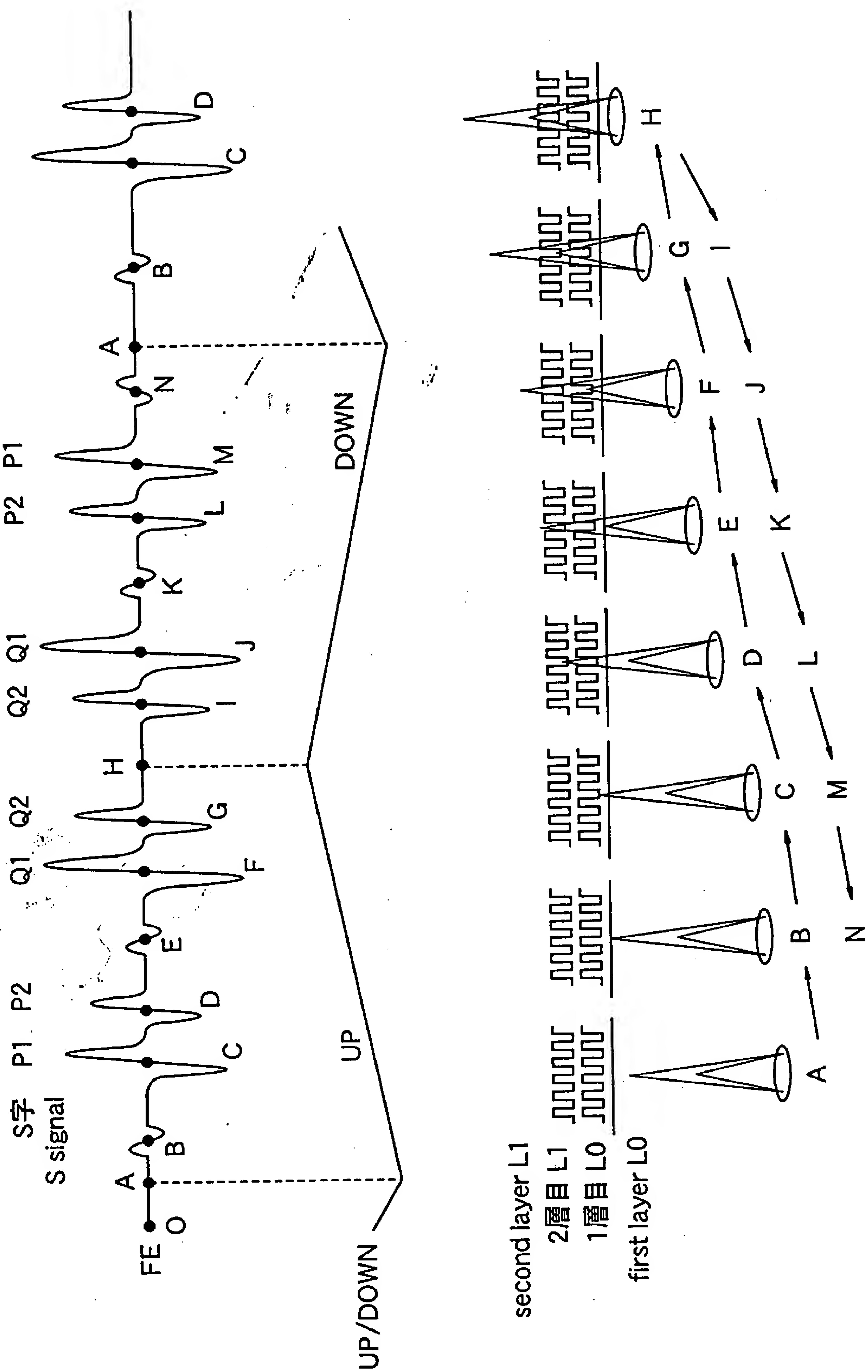


F+
F−
peak hold
ﾋﾟｰｸ ﾎｰﾙﾄﾞ
125a
125b
F+PH
F−PH
126
120
127
122
ｹﾞｲﾝ 切換
gain change
128
124
A/D
FEENV
FE
DSP
129
401
A
B
C
202
位相 補償
phase compensator

【図5】 Figure 5

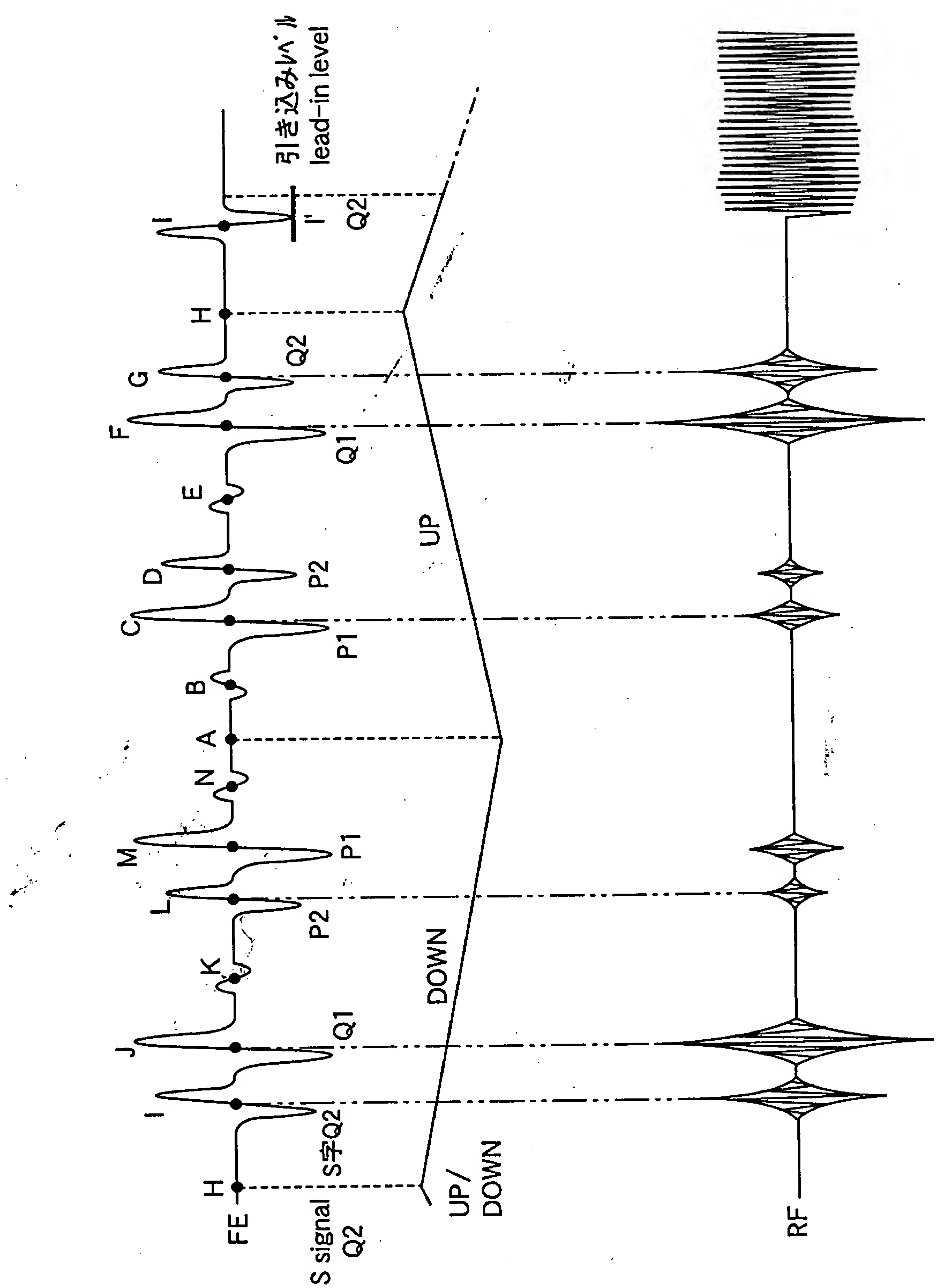

2層目 second layer
1層目 first layer
(a)
1層目 first layer
2層目 second layer
3層目 third layer
4層目 fourth layer
(b)

【図6】 Figure 6



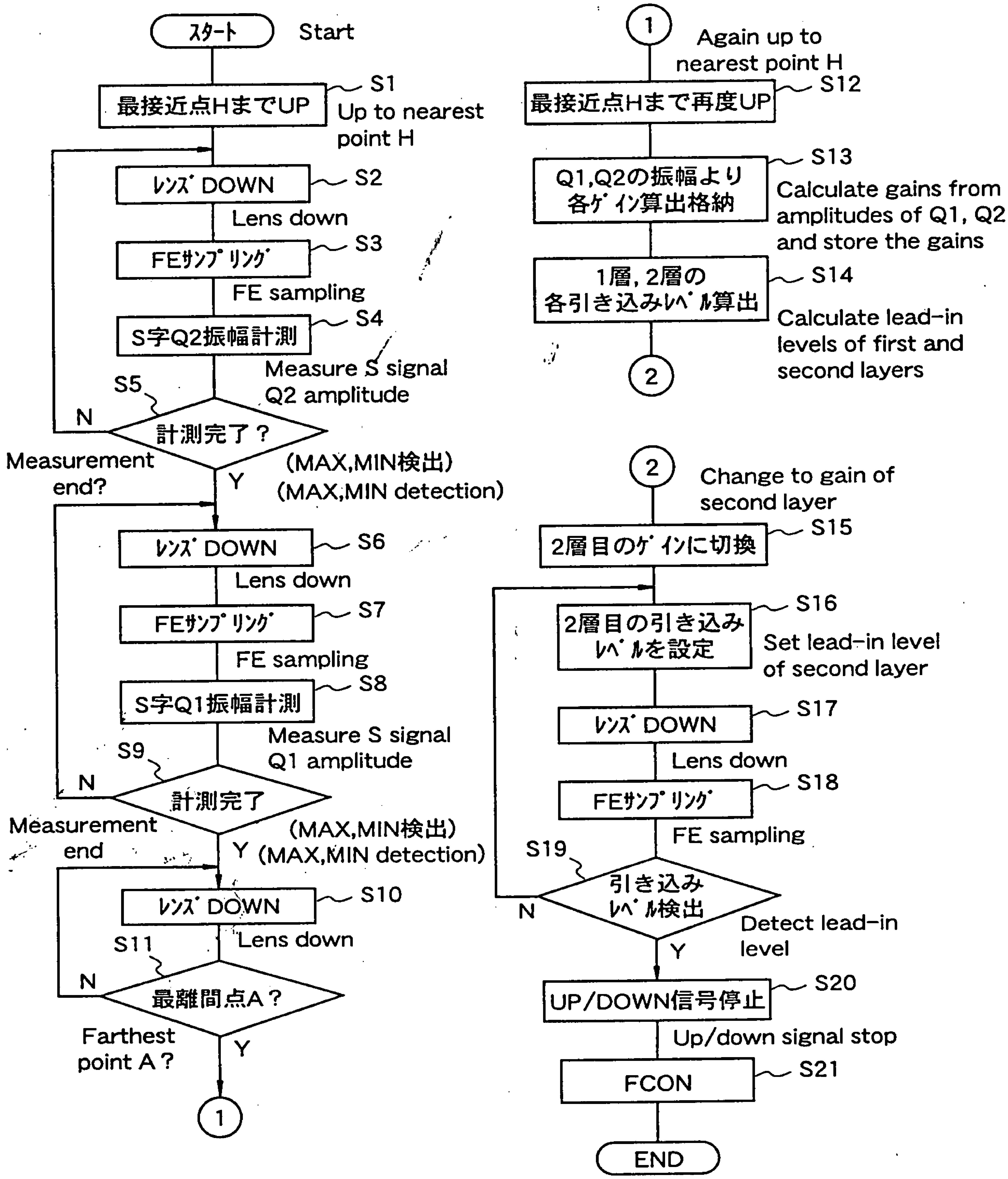
FE
S字
S signal
P1
P2
Q1
Q2
UP/DOWN
UP
DOWN
second layer L1
2層目 L1
1層目 L0
first layer L0
O
A
B
C
D
E
F
G
H
I
J
K
L
M
N

【図7】 Figure 7

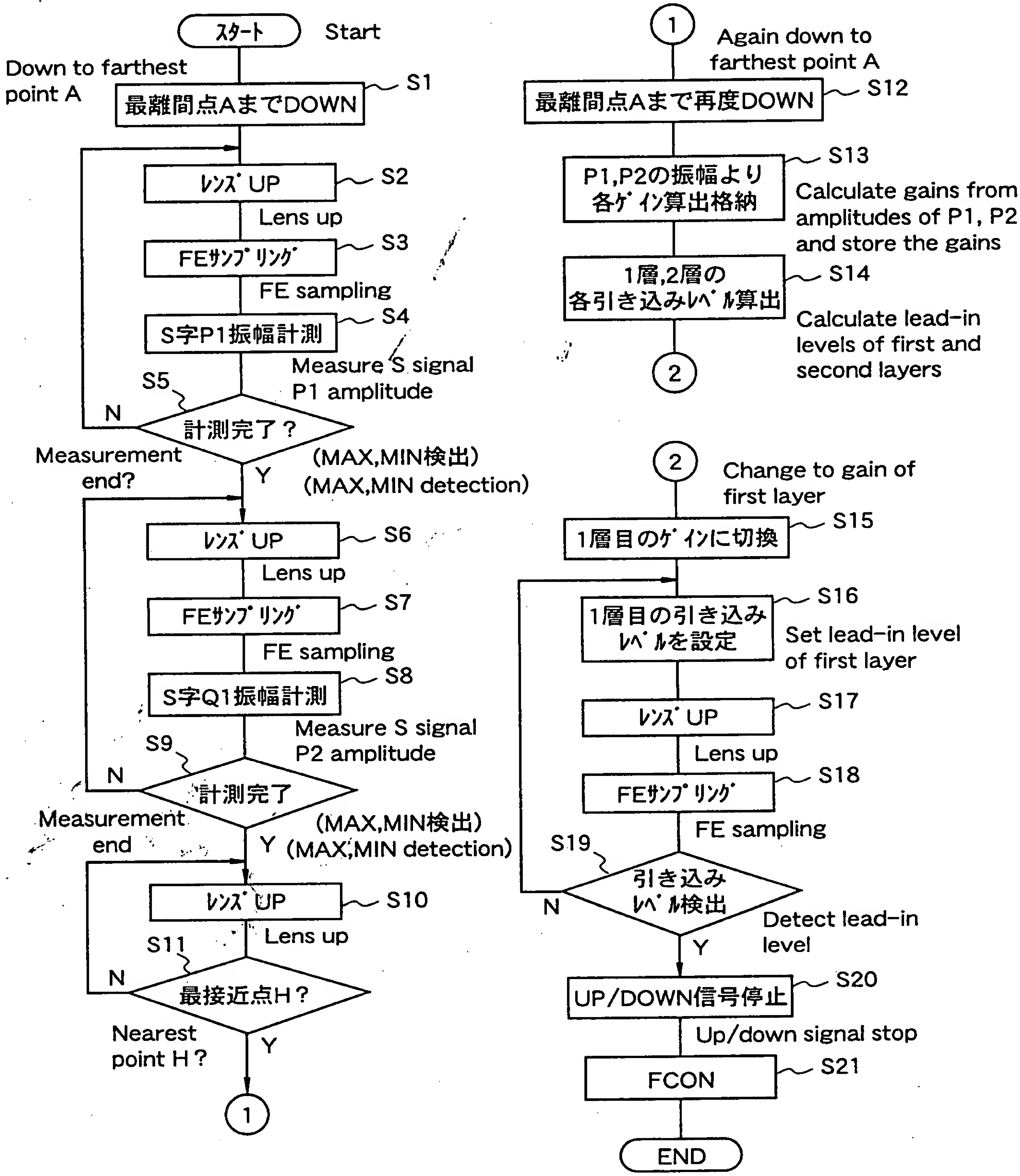


引き込みレベル
lead-in level
FE
H
I
J
K
L
M
N
A
B
C
D
E
F
G
H
I
I'
S字Q2
Q1
P2
P1
P1
P2
Q1
Q2
Q2
S signal
Q2
UP/
DOWN
DOWN
UP
RF

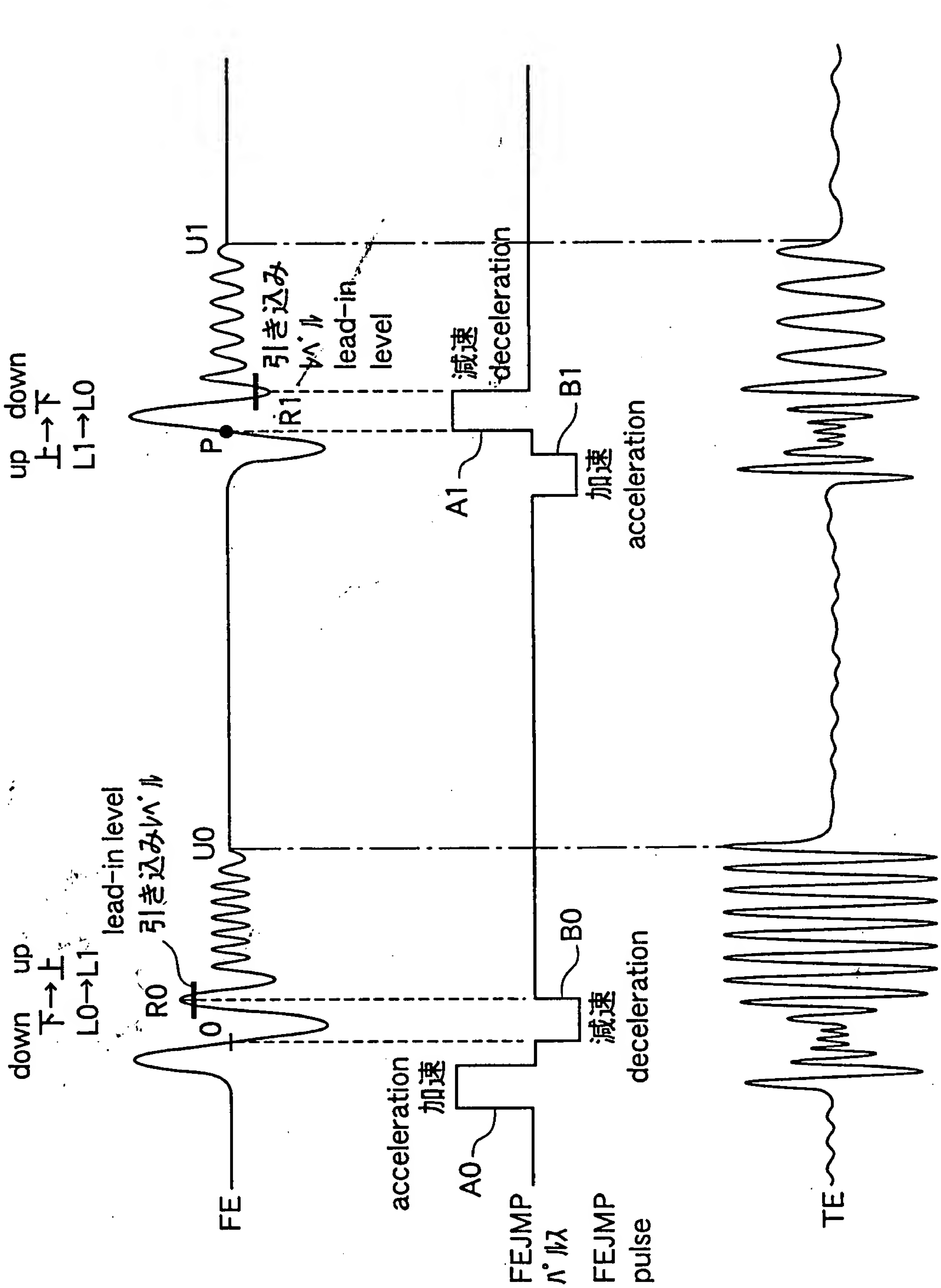
【図8】 Figure 8


スタート
Start
最接近点HまでUP
S1
Up to nearest point H
レンズ DOWN
S2
Lens down
FEサンプリング
S3
FE sampling
S字Q2振幅計測
S4
Measure S signal Q2 amplitude
S5
計測完了？
Measurement end?
(MAX,MIN検出)
(MAX,MIN detection)
N
Y
レンズ DOWN
S6
Lens down
FEサンプリング
S7
FE sampling
S字Q1振幅計測
S8
Measure S signal Q1 amplitude
S9
計測完了
Measurement end
(MAX,MIN検出)
(MAX,MIN detection)
N
Y
レンズ DOWN
S10
Lens down
S11
最離間点A？
Farthest point A?
N
Y
1
1
Again up to nearest point H
最接近点Hまで再度UP
S12
Q1,Q2の振幅より各ゲイン算出格納
S13
Calculate gains from amplitudes of Q1, Q2 and store the gains
1層, 2層の各引き込みレベル算出
S14
Calculate lead-in levels of first and second layers
2
2
Change to gain of second layer
2層目のゲインに切換
S15
2層目の引き込みレベルを設定
S16
Set lead-in level of second layer
レンズ DOWN
S17
Lens down
FEサンプリング
S18
FE sampling
S19
引き込みレベル検出
Detect lead-in level
N
Y
UP/DOWN信号停止
S20
Up/down signal stop
FCON
S21
END

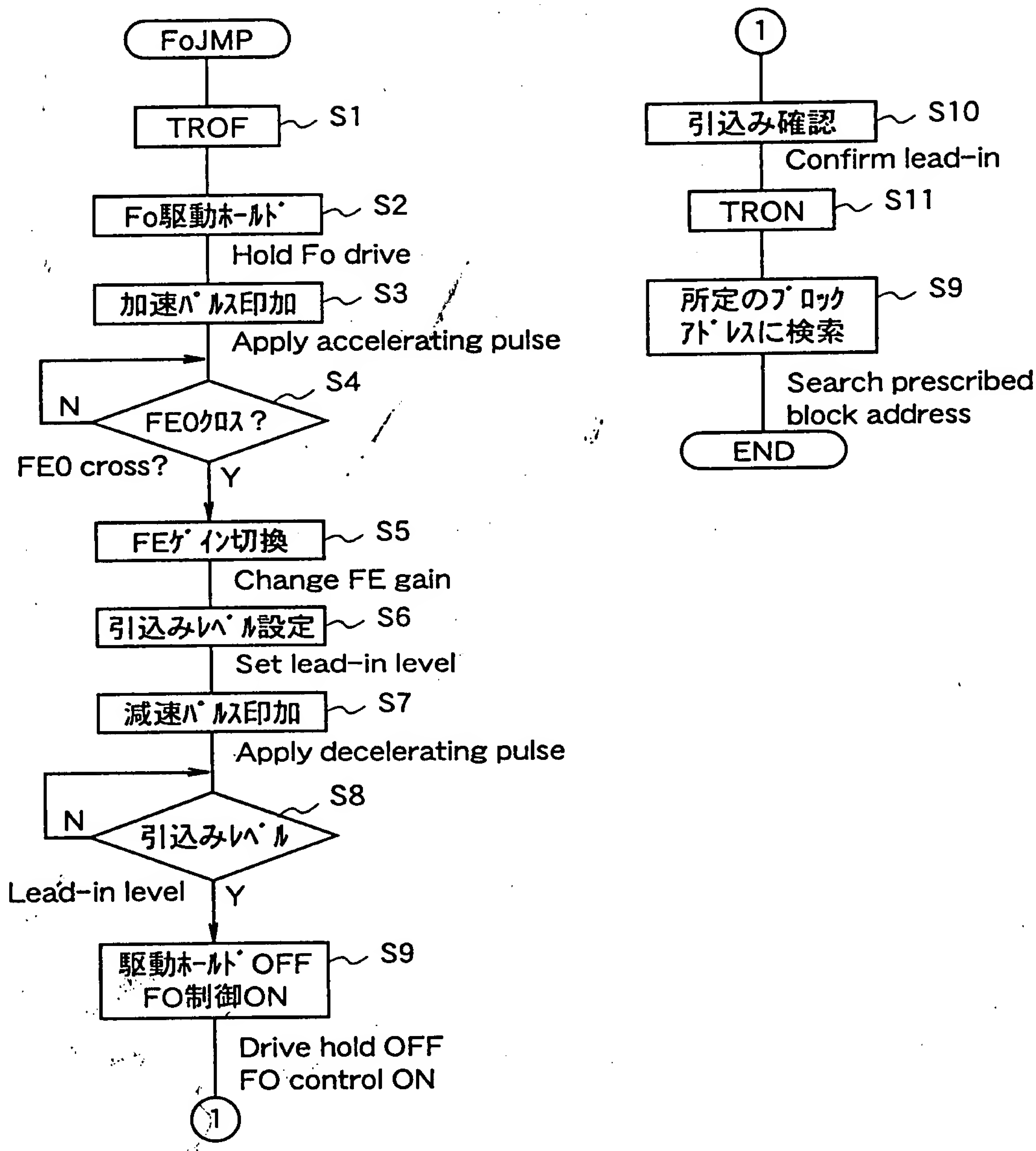
【図9】 Figure 9


スタート
Start
Down to farthest point A
最離間点AまでDOWN
S1
レンズUP
S2
Lens up
FEサンプリング
S3
FE sampling
S字P1振幅計測
S4
Measure S signal P1 amplitude
S5
計測完了？
Measurement end?
N
Y
(MAX,MIN検出)
(MAX,MIN detection)
レンズUP
S6
Lens up
FEサンプリング
S7
FE sampling
S字Q1振幅計測
S8
Measure S signal P2 amplitude
S9
計測完了
Measurement end
N
Y
(MAX,MIN検出)
(MAX,MIN detection)
レンズUP
S10
Lens up
S11
最接近点H？
Nearest point H？
N
Y
1
1
Again down to farthest point A
最離間点Aまで再度DOWN
S12
P1,P2の振幅より各ゲイン算出格納
S13
Calculate gains from amplitudes of P1, P2 and store the gains
1層,2層の各引き込みレベル算出
S14
Calculate lead-in levels of first and second layers
2
2
Change to gain of first layer
1層目のゲインに切換
S15
1層目の引き込みレベルを設定
S16
Set lead-in level of first layer
レンズUP
S17
Lens up
FEサンプリング
S18
FE sampling
S19
引き込みレベル検出
Detect lead-in level
N
Y
UP/DOWN信号停止
S20
Up/down signal stop
FCON
S21
END

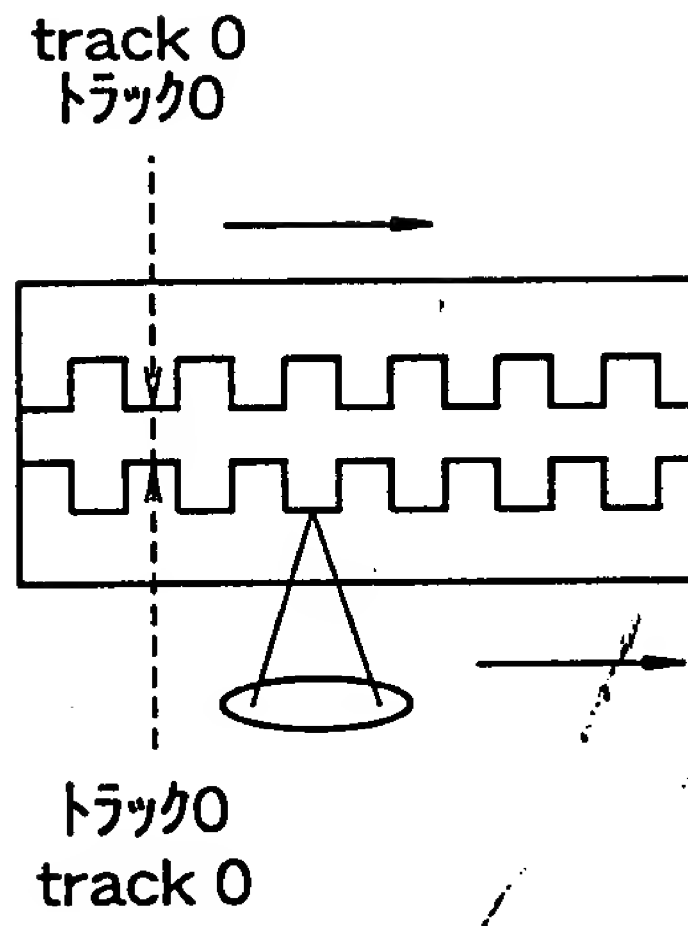
【図10】 Figure 10



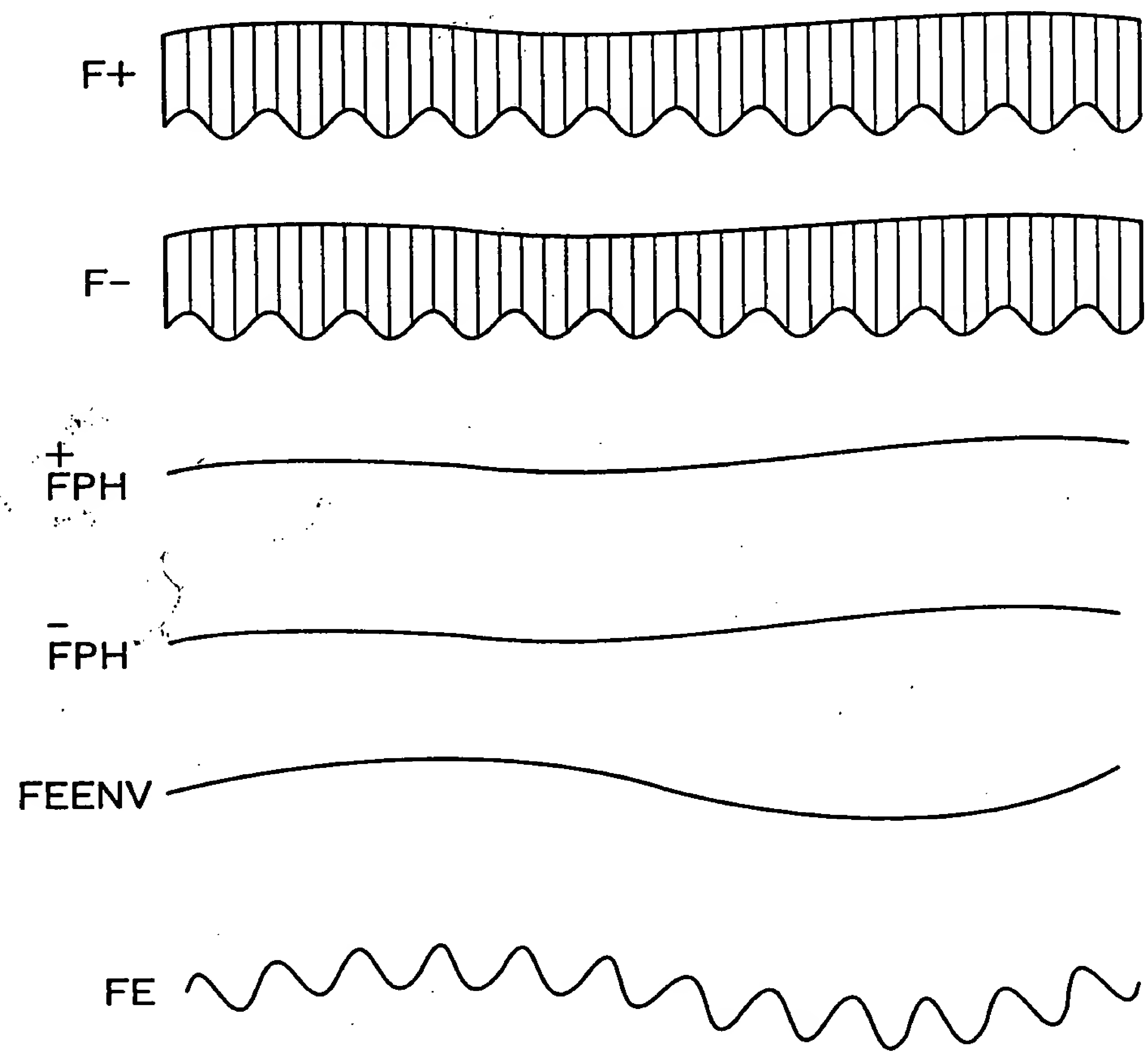
【図11】 Figure 11



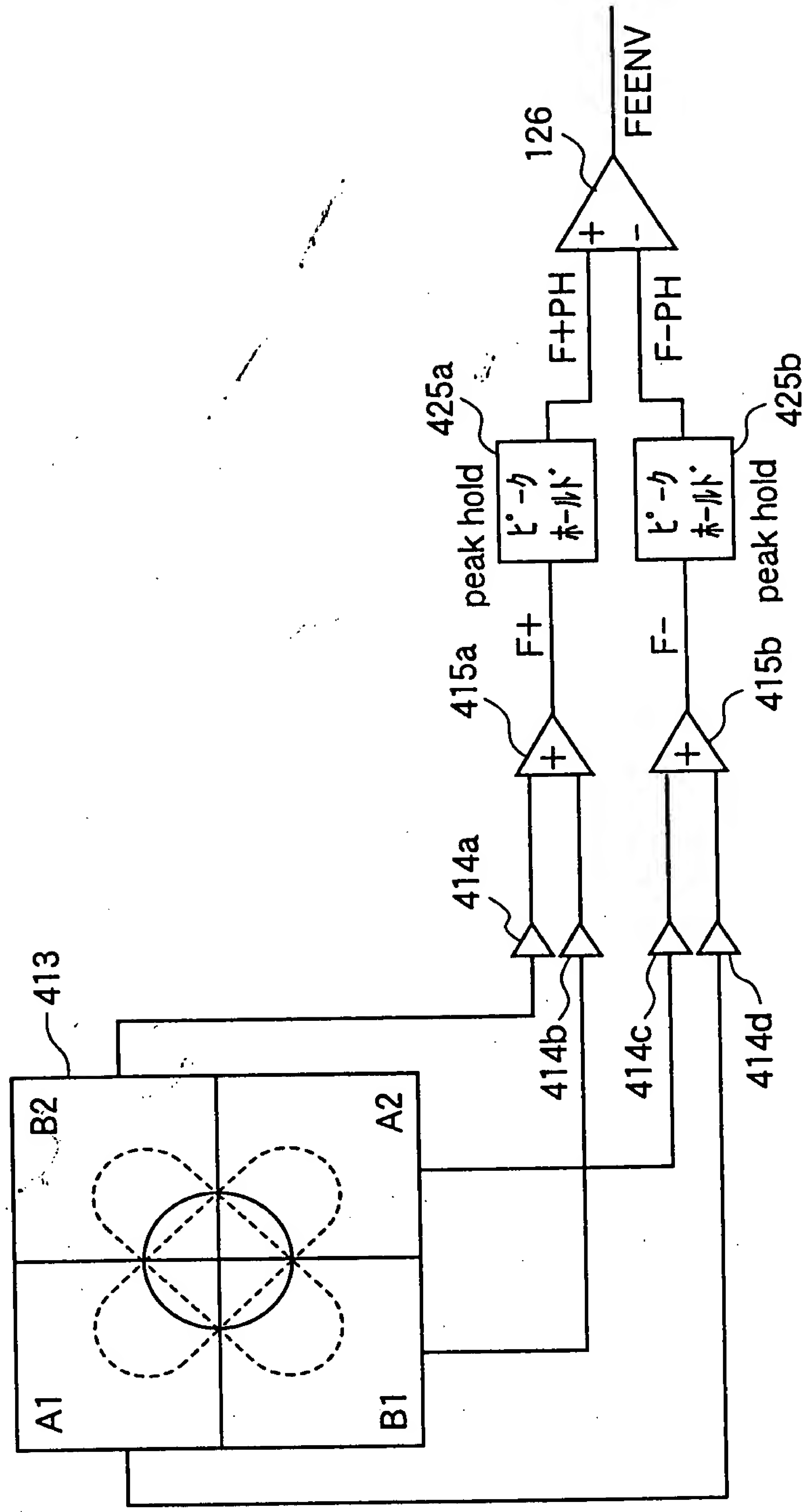
【図12】 Figure 12



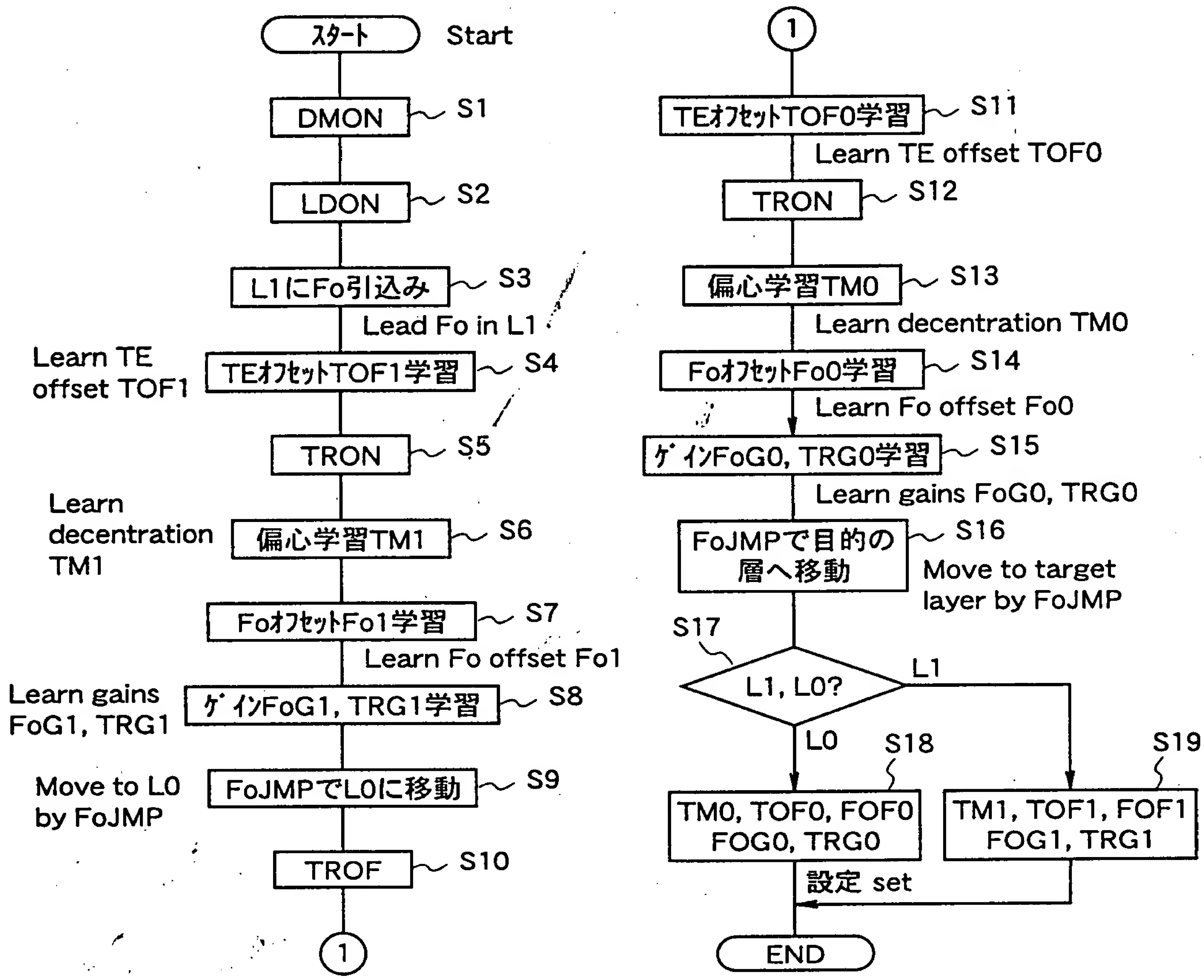

【図13】 Figure 13



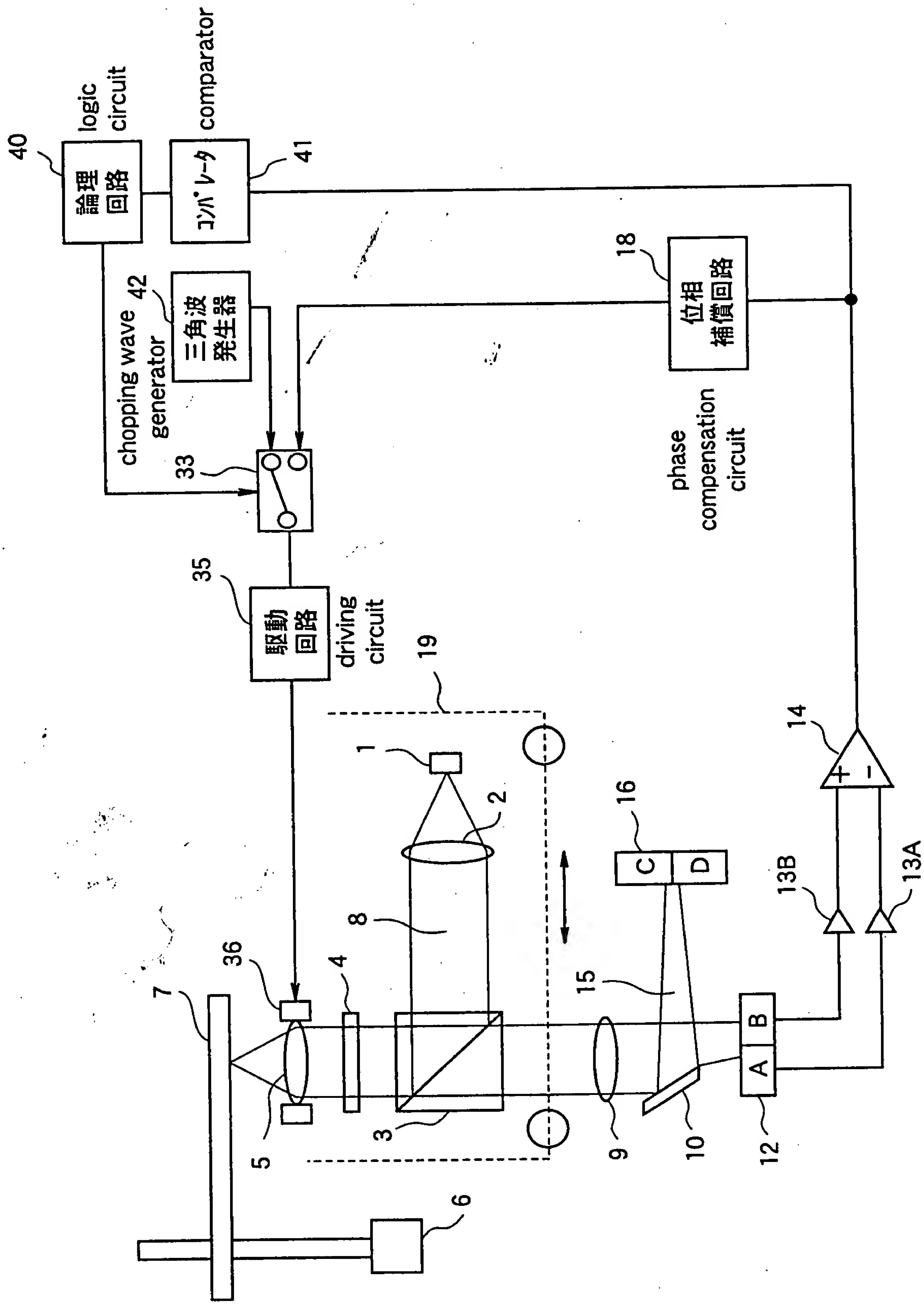
【図14】 Figure 14



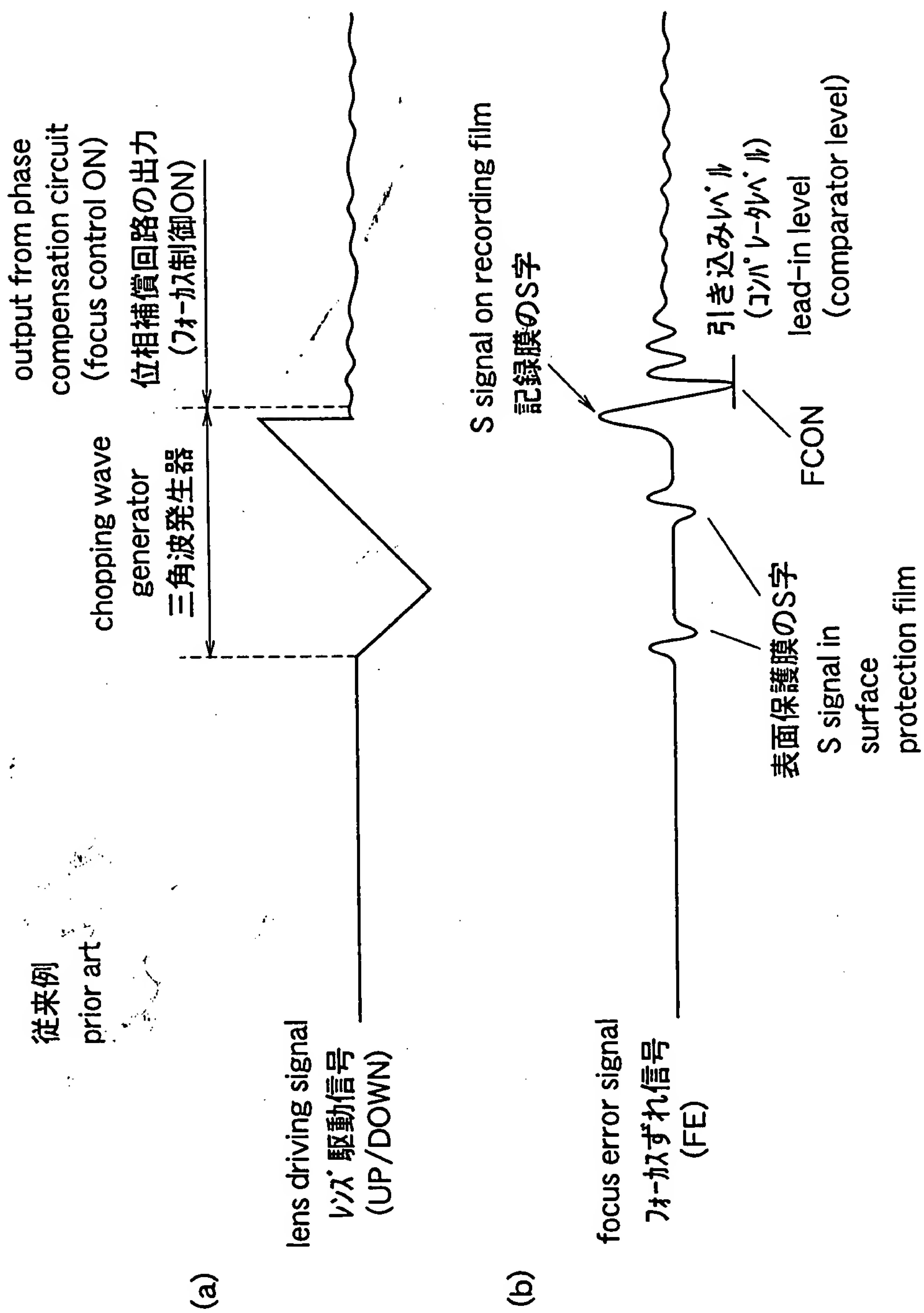
【図15】 Figure 15



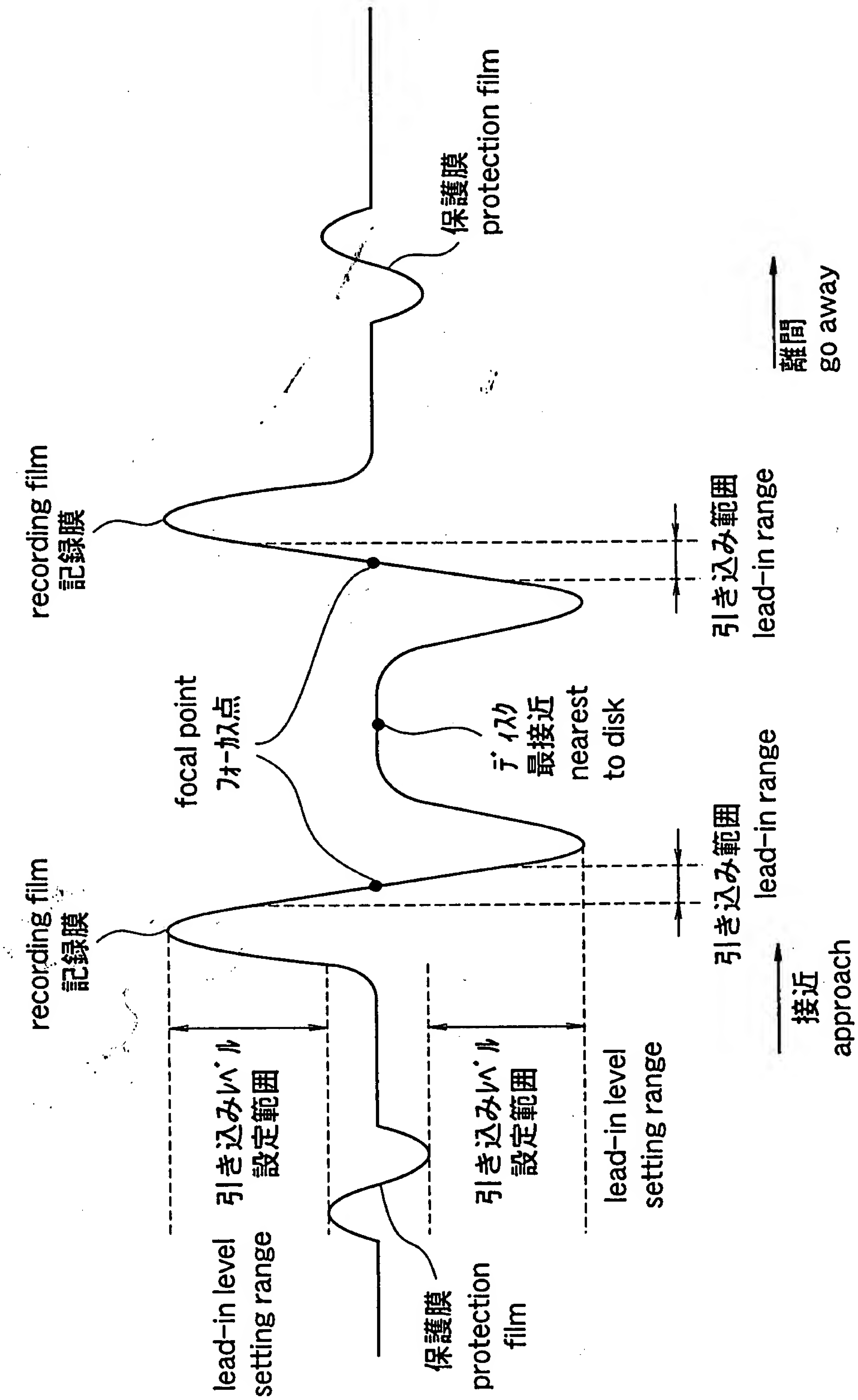
【図16】 Figure 16



【図17】 Figure 17



【図18】 Figure 18



【図19】 Figure 19